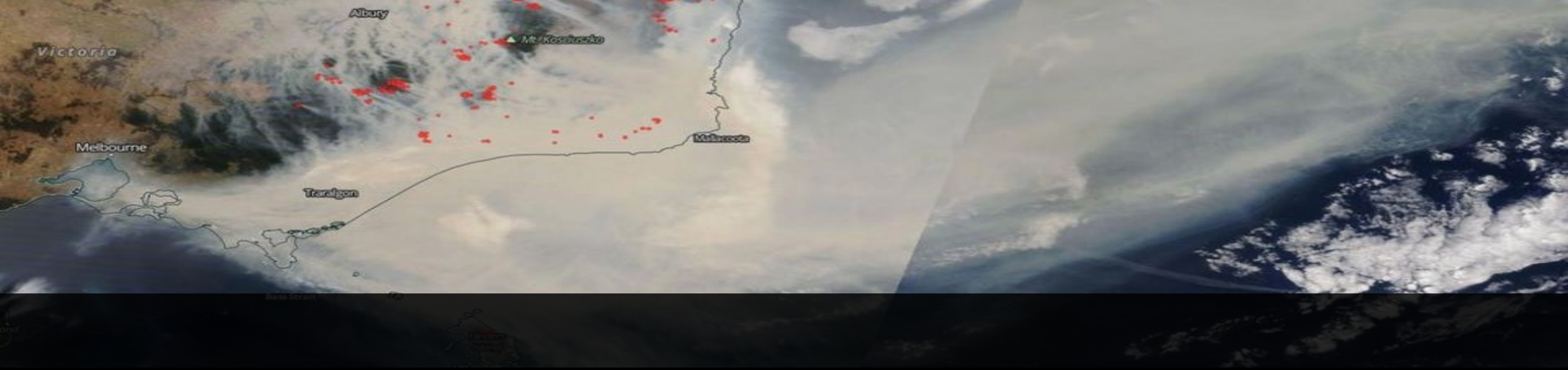


Exploring the Climate Response to Recent Wildfires

with CESM2 and CERES Data

John Fasullo, NCAR

Nan Rosenbloom, NCAR

And numerous other NCAR collaborators

27 Apr 2022

2022 CERES Spring Science Team Meeting, Virtual

catalyst

Cooperative agreement to analyze variability, change and predictability in the earth system

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Science Questions

Wildfires lie at the nexus of various hot topics

Earth's Energy Imbalance

What is the cumulative influence of wildfire aerosols on Earth's energy budget and imbalance?

What influence do wildfire emissions have on the evolution of El Niño and La Niña events?

ENSO

As the globe warms, how do wildfire emissions change; and what is the sign and magnitude of this climate feedback?

Climate Change

How do wildfire aerosols effect radiation and the optical properties of clouds?

Cloud-climate interactions

Wildfire and Climate Change

Wildfire has become pervasive.

Boulder 30 Dec 2021
>1000 homes destroyed

Taken from NCAR

4 largest fires in state history

Colorado Wildfires 2020

California 2021

Wildfire and Climate Change

In 2022, fires have continued to drive mass evacuations in Boulder County.

Strong wind events (typical of winter/spring) have coincided with unusually dry conditions with very low RH; more characteristic of summer conditions.

Intersection of these seasons has led to significant increases in fire risk and numerous fires. We remain at critical fire risk levels. Climate projections show a continued increase in risk.

The New York Times

Colorado Wildfire Scorches Nearly 190 Acres and Prompts Evacuations

The blaze, known as the NCAR fire, at its peak led to the evacuation of 19,000 people near Boulder. Officials said there were no injuries or structures damaged.

Give this article

Boulder March 2022

An air tanker over the NCAR fire near the National Center for Atmospheric Research on Saturday in Boulder, Colo. Helen H. Richardson/The Denver Post, via Associated Press

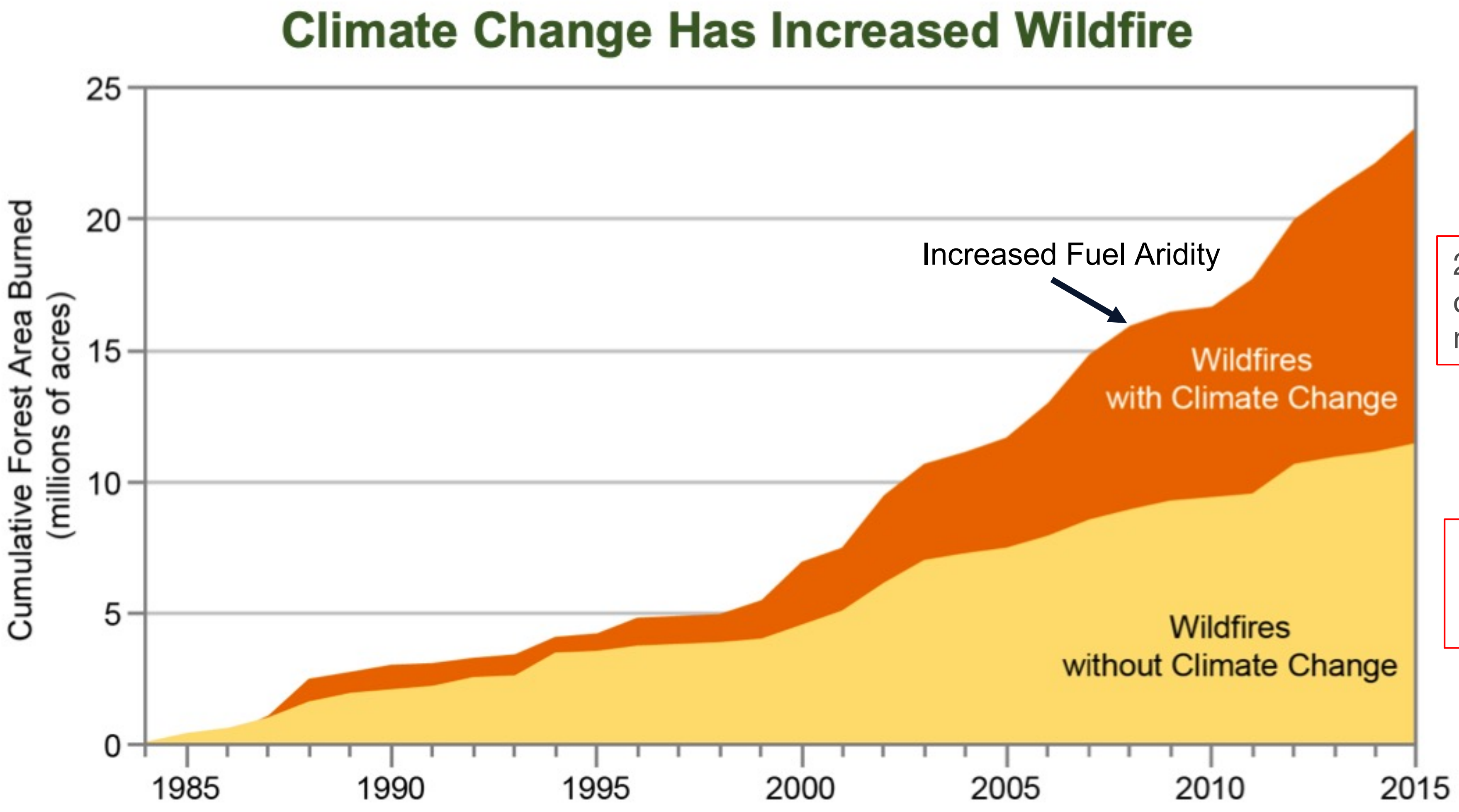
By Vimal Patel and Eduardo Medina

March 27, 2022

A fire near Boulder, Colo., that had burned nearly 190 acres as of Sunday morning prompted the authorities to evacuate 19,000 people over the weekend, officials said. About 1,600 people and nearly 700 homes remained in an evacuation zone on Sunday.

The wind-fueled wildfire, which was named the NCAR fire because it started near the National Center for Atmospheric Research, was 21 percent contained, the authorities said at a news conference on Sunday. No damage or injuries were reported.

More than 200 firefighters were in the air and on the ground trying to keep the fire away from neighborhoods.



The cumulative forest area burned by wildfires has greatly increased between 1984 and 2015, with analyses estimating that the area burned by wildfire across the western United States over that period was twice what would have burned had climate change not occurred. *From Figure 25.4 (Source: adapted from Abatzoglou and Williams 2016).*

21st C trends depicted in climate models!

Climate effects assumed to be small. **But are they?**

Outline

1. The climate response to the 2019/20 Australian bushfires.
2. The simulated climate response to CMIP6 prescribed biomass burning in CESM2.
3. Ongoing work: wildfire as a coupled component of ENSO and climate feedback
4. A central role for CERES data in CESM development.

CERES Data

CERES data used in this work:

CERES EBAF4.1; monthly Mar 2000-Dec 2021

Follow-on work will make use of the radiation perturbation fields from Loeb et al. 2020

The Flux-by-Cloud-Type fields will also play a key role in follow-on model evaluation activities.

JGR Atmospheres

Research Article | Open Access

Changes in Clear-Sky Shortwave Aerosol Direct Radiative Effects Since 2002

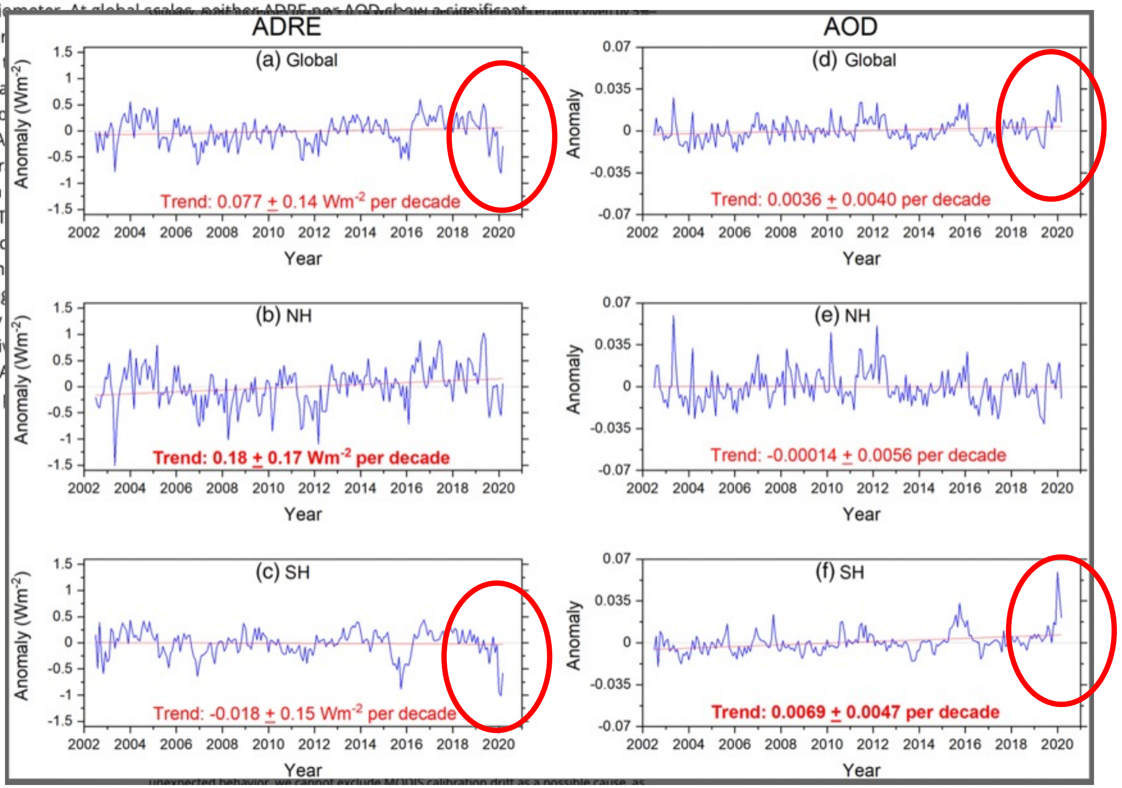
Norman G. Loeb, Wenying Su, Nicolas Bellouin, Yi Ming

First published: 08 February 2021 | https://doi.org/10.1029/2020JD034090 | Citations: 4

SECTIONS PDF TOOLS SHARE

Abstract

A new method for determining clear-sky shortwave aerosol direct radiative effects (ADRE) from the Clouds and the Earth's Radiant Energy System is used to examine changes in ADRE since 2002 alongside changes in aerosol optical depth (AOD) from the Moderate Resolution Spectroradi
trend. Over the norther
decade (less reflection
hemisphere. The increa
United States, and Euro
either global ADRE or A
in March 2020. In contr
variability even though
February than March. T
humid over China, whic
meteorology and norm
substantially, exceeding
correspond to the only
interval for 2 consecuti
China are observed in A
albedo on ADRE in the



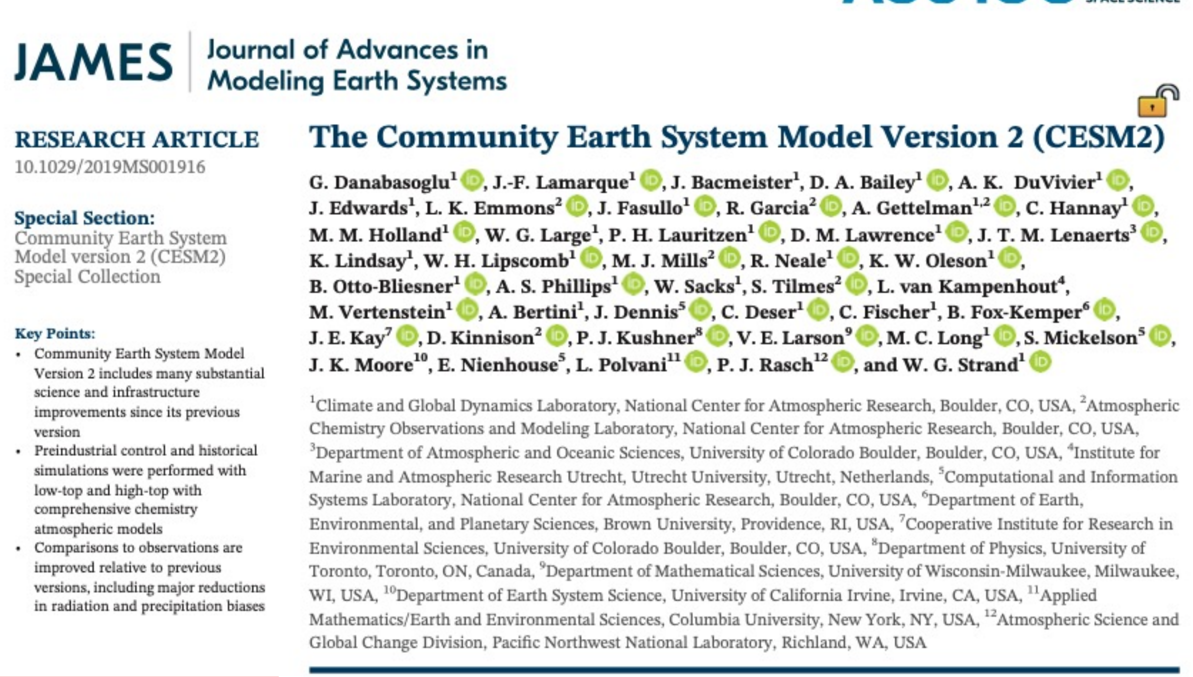
Loeb et al. 2021 showed that the dominant clear-sky global anomaly during CERES (in AOD and ADRE) was in early 2020 and was coincident with the Australian wildfires.

The Community Earth System Model Version 2

All simulations used in this talk:

1) Are fully coupled. Most are uninitialized.
2) Use the default 1-deg CESM2 configuration.
3) Use a unified turbulence/cloud scheme, Cloud Layers Unified By Binormals (CLUBB; Golaz et al., 2002; Larson, 2017)
4) Represent the 1st and 2nd cloud aerosol indirect effects – these effects are not widely represented in CMIP6 models generally but are fundamental to the wildfire responses we find.
5) Use fire emissions estimated from GFED (MODIS-based satellite retrievals since 1997) or background clim. from CMIP6 scenarios.

Danabasoglu et al. 2020



JAMES Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE

10.1029/2019MS001916

Special Section:
Community Earth System Model version 2 (CESM2) Special Collection

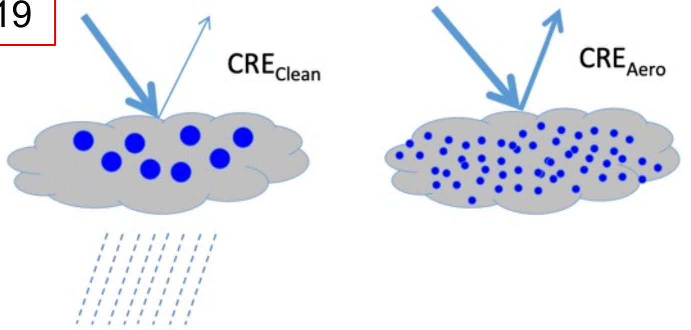
Key Points:
- Community Earth System Model Version 2 includes many substantial science and infrastructure improvements since its previous version
- Preindustrial control and historical simulations were performed with low-top and high-top with comprehensive chemistry atmospheric models
- Comparisons to observations are improved relative to previous versions, including major reductions in radiation and precipitation biases

The Community Earth System Model Version 2 (CESM2)

G. Danabasoglu[1], J.-F. Lamarque[1], J. Bacmeister[1], D. A. Bailey[1], A. K. DuVivier[1], J. Edwards[1], L. K. Emmons[2], J. Fasullo[1], R. Garcia[2], A. Gettelman[1,2], C. Hannay[1], M. M. Holland[1], W. G. Large[1], P. H. Lauritzen[1], D. M. Lawrence[1], J. T. M. Lenaerts[3], K. Lindsay[1], W. H. Lipscomb[1], M. J. Mills[2], R. Neale[1], K. W. Oleson[1], B. Otto-Bliesner[1], A. S. Phillips[1], W. Sacks[1], S. Tilmes[2], L. van Kampenhout[4], M. Vertenstein[1], A. Bertini[1], J. Dennis[5], C. Deser[1], C. Fischer[1], B. Fox-Kemper[6], J. E. Kay[7], D. Kinnison[2], P. J. Kushner[8], V. E. Larson[9], M. C. Long[1], S. Mickelson[5], J. K. Moore[10], E. Nienhouse[5], L. Polvani[11], P. J. Rasch[12], and W. G. Strand[1]

[1]Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, USA, [2]Atmospheric Chemistry Observations and Modeling Laboratory, National Center for Atmospheric Research, Boulder, CO, USA, [3]Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder, Boulder, CO, USA, [4]Institute for Marine and Atmospheric Research Utrecht, Utrecht University, Utrecht, Netherlands, [5]Computational and Information Systems Laboratory, National Center for Atmospheric Research, Boulder, CO, USA, [6]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI, USA, [7]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO, USA, [8]Department of Physics, University of Toronto, Toronto, ON, Canada, [9]Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI, USA, [10]Department of Earth System Science, University of California Irvine, Irvine, CA, USA, [11]Applied Mathematics/Earth and Environmental Sciences, Columbia University, New York, NY, USA, [12]Atmospheric Science and Global Change Division, Pacific Northwest National Laboratory, Richland, WA, USA

Gettelman et al. 2019



Brighter clouds (albedo effect) with smaller drops (S. Twomey 1977)
Also: delay in precipitation (B. Albrecht, 1989). Longer lived Clouds?

Overarching Science Question

Is the global-scale climate response to wildfire negligible, and if not, what is the character of the response and what drives it?

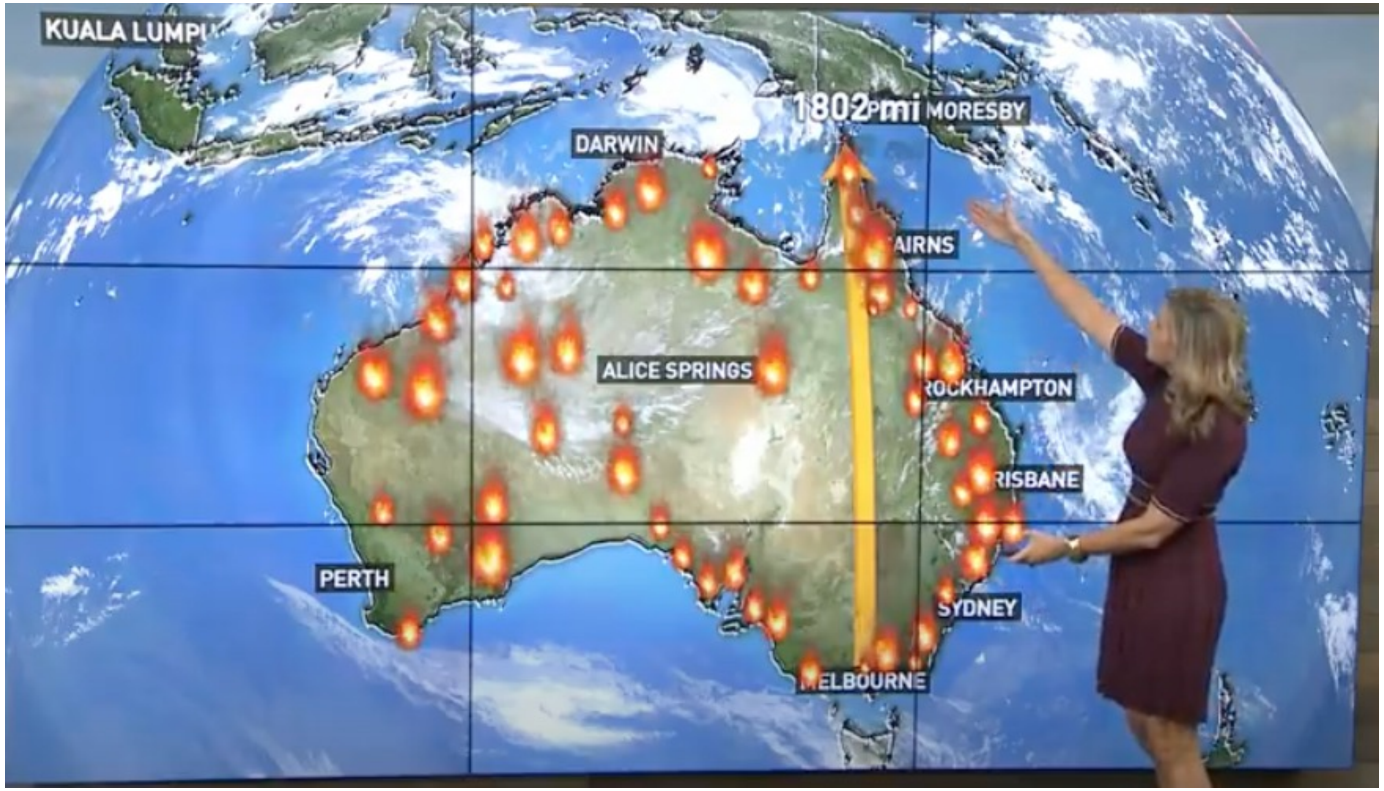
Overarching Science Question

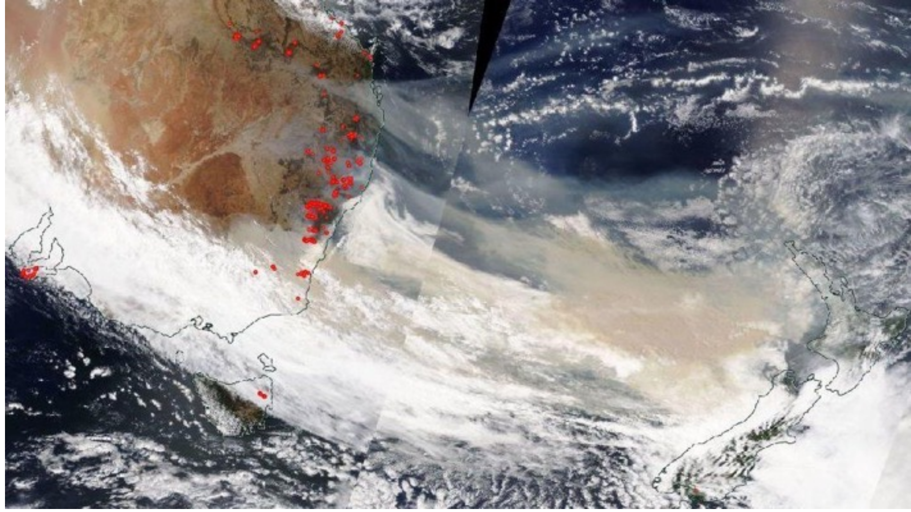
Is the global-scale climate response to wildfire negligible, and if not, what is the character of the response and what drives it?

These questions will be explored in 2 main contexts:
1) 2019/20 Australian wildfires
2) The satellite era of wildfire in CMIP6 (1997-2014)

1) Impacts of 2019-20 Australian Wildfires on Climate / ENSO

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Australian Wildfire and COVID-19 Emissions Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.15 (2021): e2021GL093841)





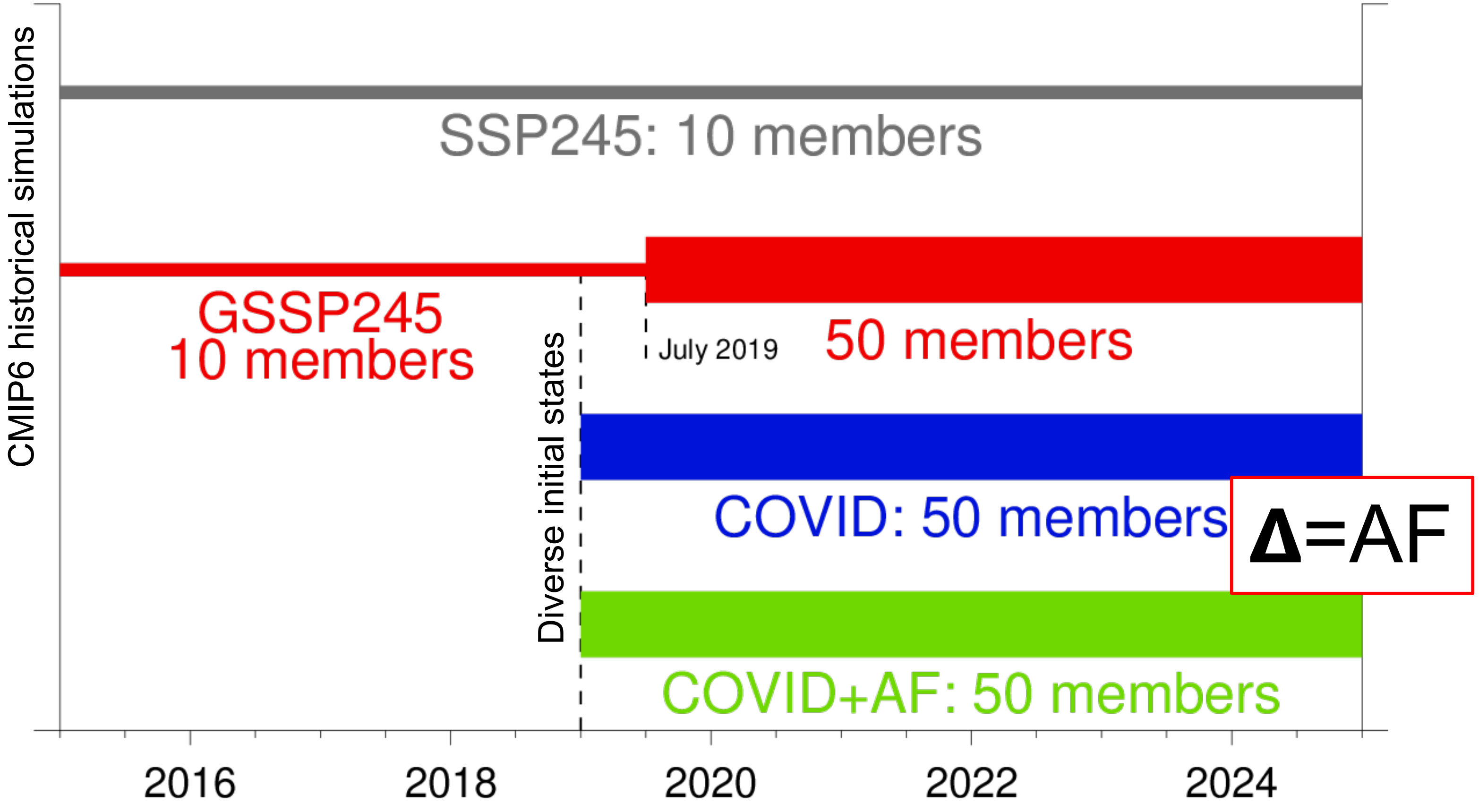
Smoke is advected from wildfire hotspots (red) during the record-breaking 2019/20 Australian bushfire season, as observed from space on 5 Jan. (source: NASA Worldview)

- Worst bushfire season on record
- Over 60 million acres burned.
- Almost 10,000 buildings destroyed.
- Over 1 billion animals killed.
- >A$100 billion in damage – costliest natural disaster to date.

Fasullo et al. 2021, GRL

1) Impacts of 2019-20 Australian Wildfires on Climate / ENSO

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Australian Wildfire and COVID-19 Emissions Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.15 (2021): e2021GL093841)



Experimental Setup

Stemmed from a desire to quantify the response to COVID emissions reductions.

Key Finding: The major forced climate anomaly in 2020 was driven by the Australian wildfires, not the emissions reductions due to COVID.

Fasullo et al. 2021, GRL

1) Impacts of 2019-20 Australian Wildfires on Climate / ENS

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Aust
Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.1

- The reductions in aerosol burdens due to COVID were easily detectible in the zonal mean.
- But their radiative effects were small and did not rise above internal variability, even in a 50-member ensemble.
- In contrast the Australian fires had a significant detectible radiative effect, both in SW (left) and net (right) fluxes.

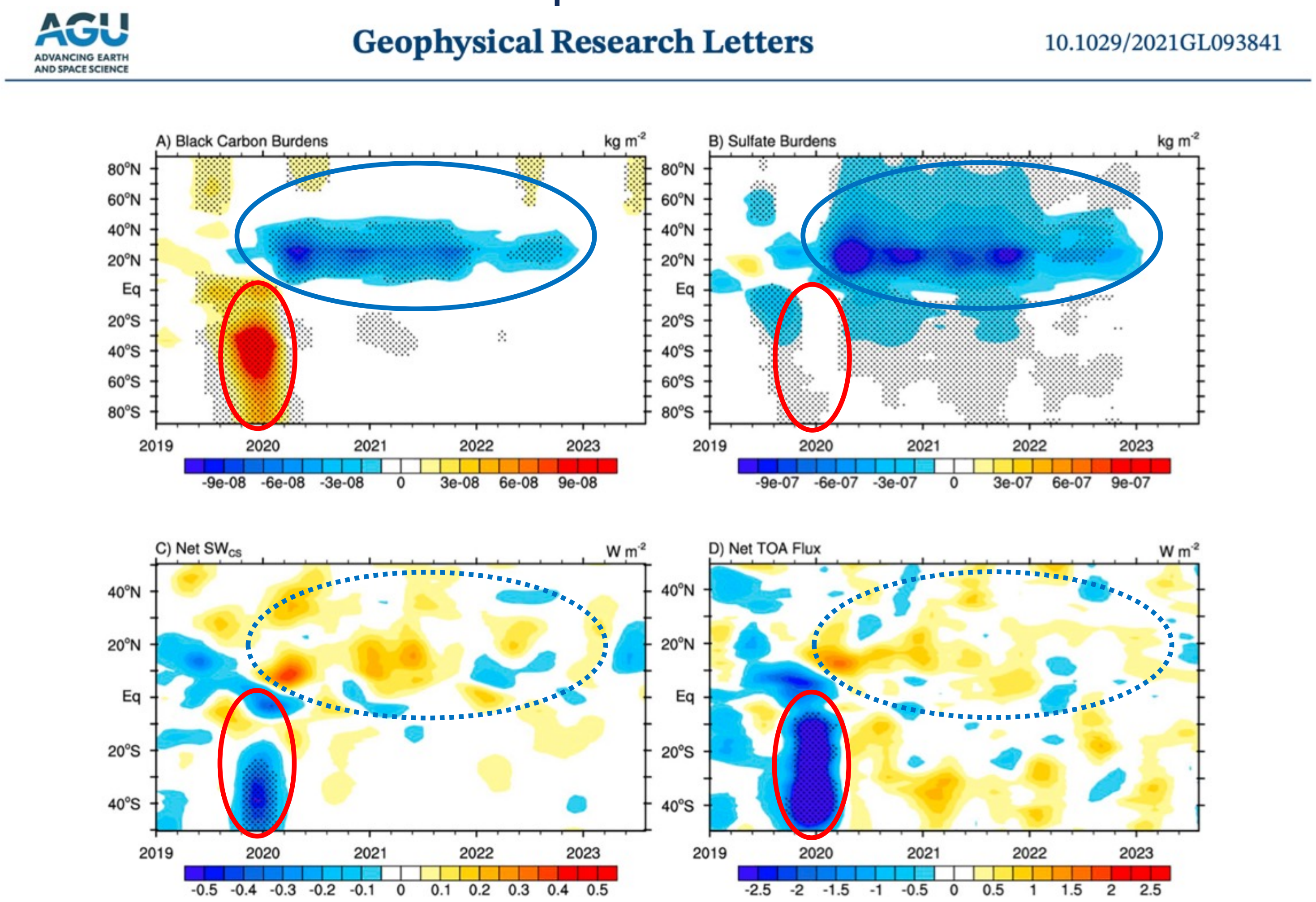


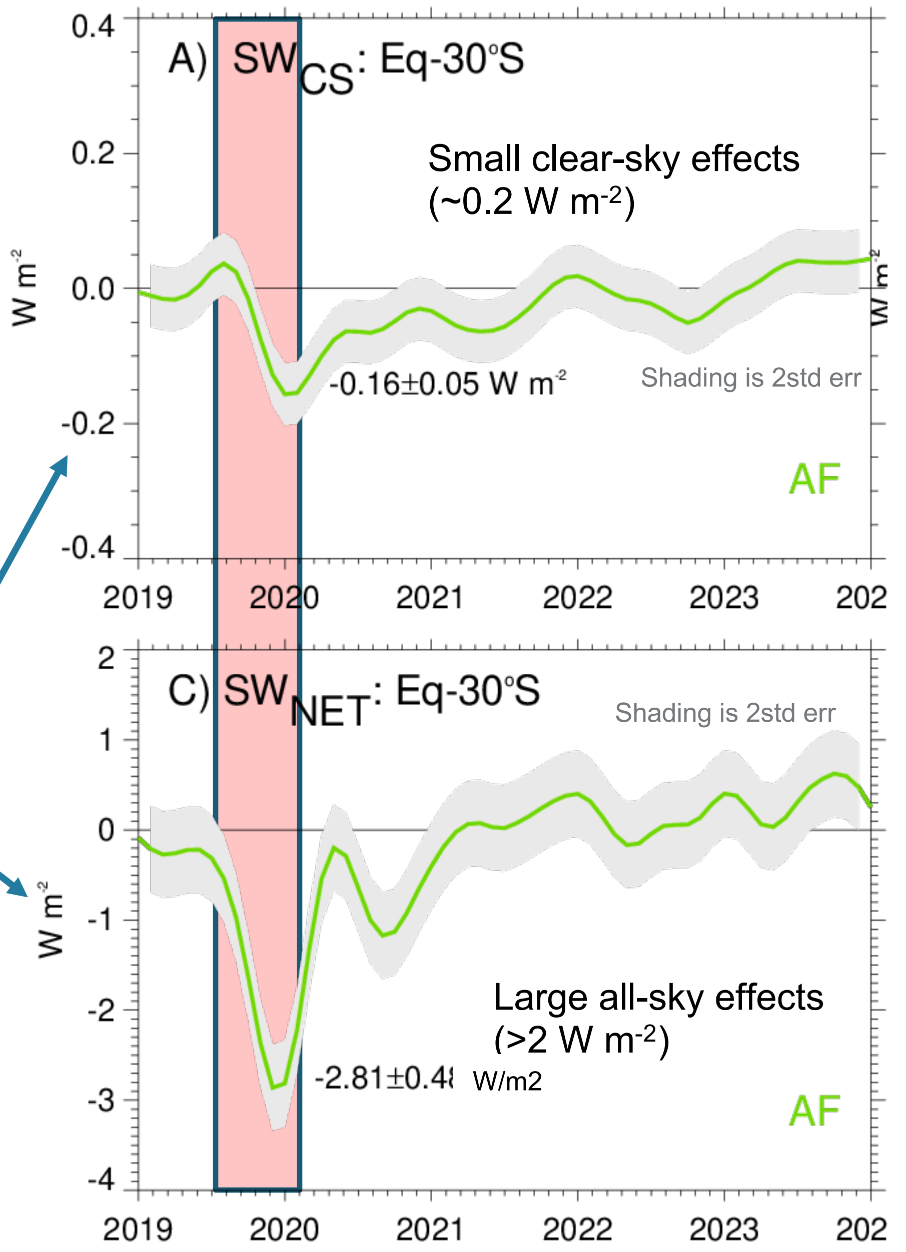
Figure 2. Zonal- and ensemble-mean evolution of COVID + AF differences with GSSP245 in (a) black carbon and (b) sulfate aerosol burdens, and net top-of-atmosphere clear-sky shortwave (c) and net radiative flux (d). Stippling indicates regions of where differences exceed twice the ensemble standard error and fields are plotted through 2023 to focus on detectable differences.

Fasullo et al. 2021, GRL

1) Impacts of 2019-20 Australian Wildfires on Climate / ENSO

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Australian Wildfire and COVID-19 Emissions Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.15 (2021): e2021GL093841)

Emissions from the 2019/20 Australian bushfires drove a robust climate response, on par with a major volcanic eruption (and much stronger than COVID emissions reductions).

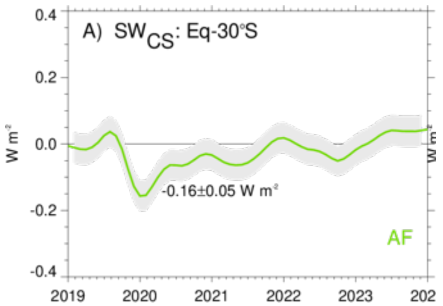


Fasullo et al. 2021, GRL

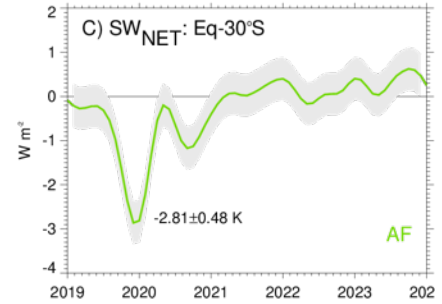
Impacts of 2019-20 Australian Wildfires on Climate / ENSO

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Australian Wildfire and COVID-19 Emissions Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.15 (2021): e2021GL093841)

The response was driven by aerosol cloud interactions – reducing cloud droplet size, extending lifetime, and increasing albedo.
The associated simulated interhemispheric radiative imbalance anomaly is greater than at any time since 1850 (CESM2 LE).

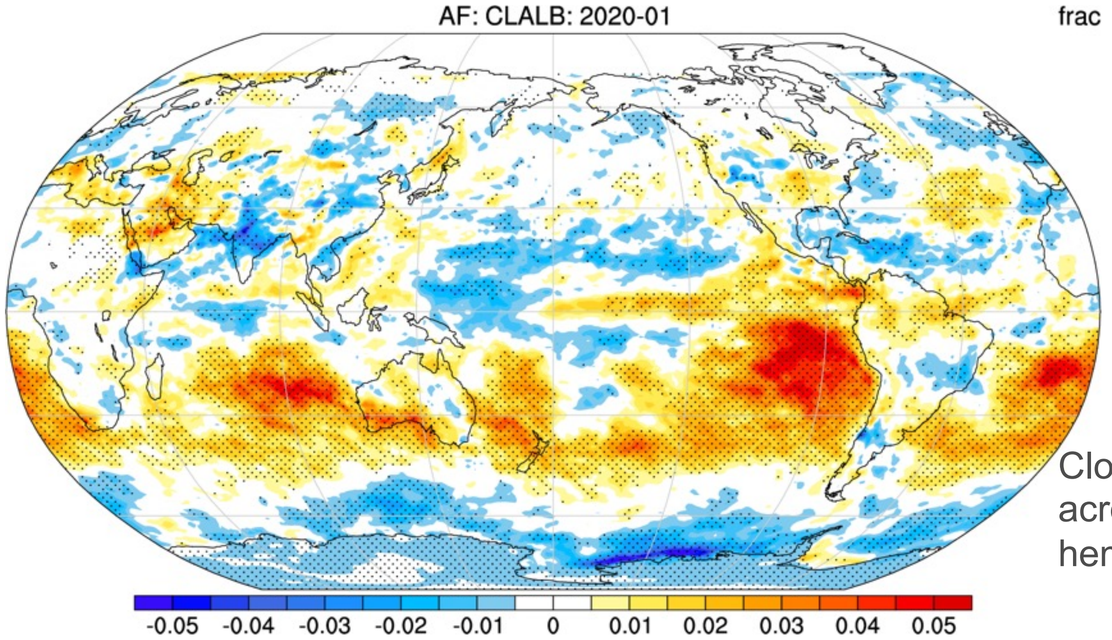


Small clear-sky effects (~ 0.2 W m^{-2})

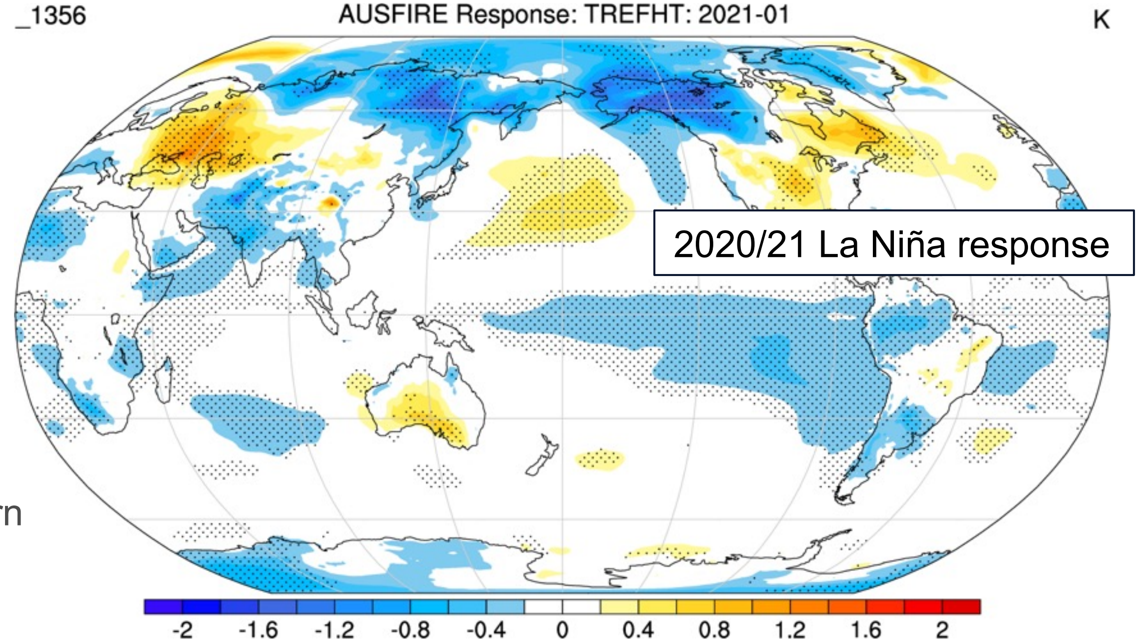


Large all-sky effects (>2 W m^{-2})

Cloudy Sky Albedo: Response to Fires (Jan 2020)



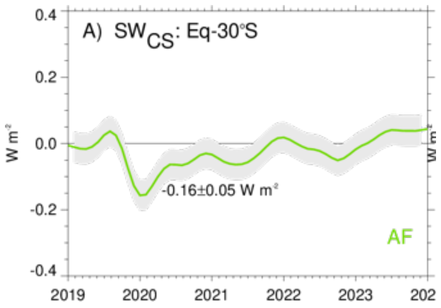
Cloud brightening across the southern hemisphere



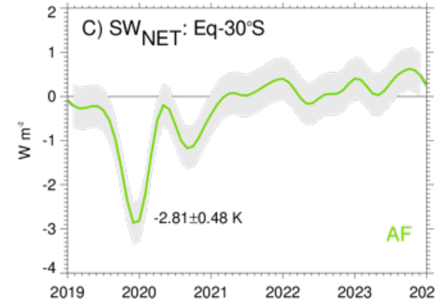
2020/21 La Niña response

Impacts of 2019-20 Australian Wildfires on Climate / ENSO

(Fasullo, et al. 2021, "Coupled Climate Responses to Recent Australian Wildfire and COVID-19 Emissions Anomalies Estimated in CESM2." *Geo. Res. Lett* 48.15 (2021): e2021GL093841)



Small clear-sky effects ($\sim$0.2 W m^{-2})

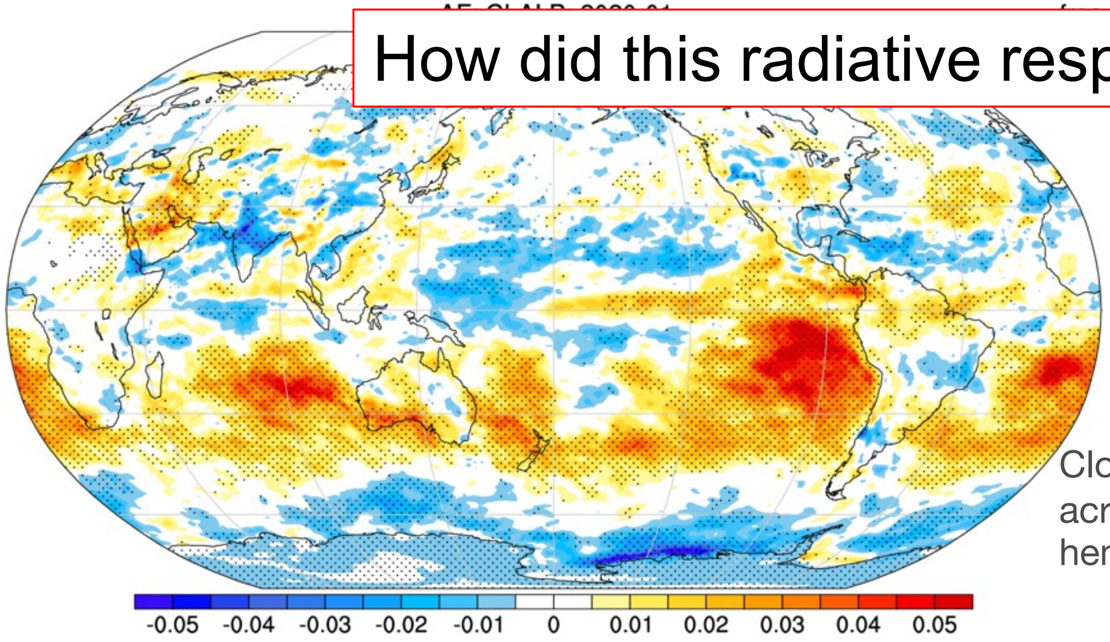


Large all-sky effects (>2 W m^{-2})

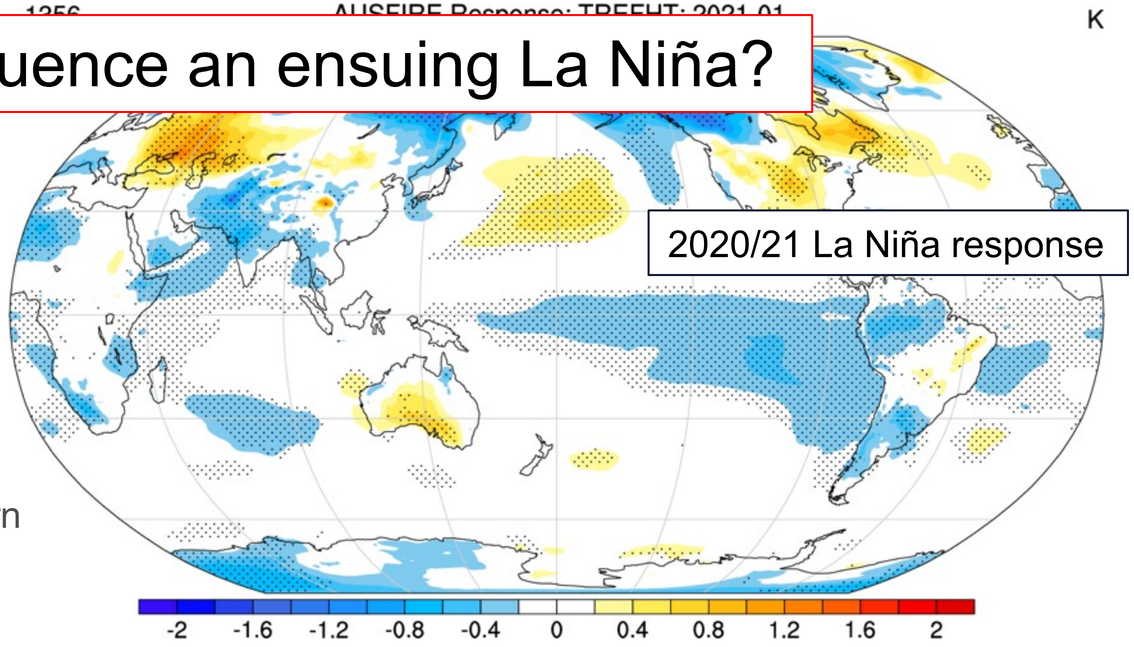
The response was driven by aerosol cloud interactions – reducing cloud droplet size and increasing albedo.
The associated simulated interhemispheric radiative imbalance anomaly is greater than at any time since 1850 (CESM2 LE).

Cloudy Sky Albedo: Response to Fires (Jan 2020)

How did this radiative response influence an ensuing La Niña?

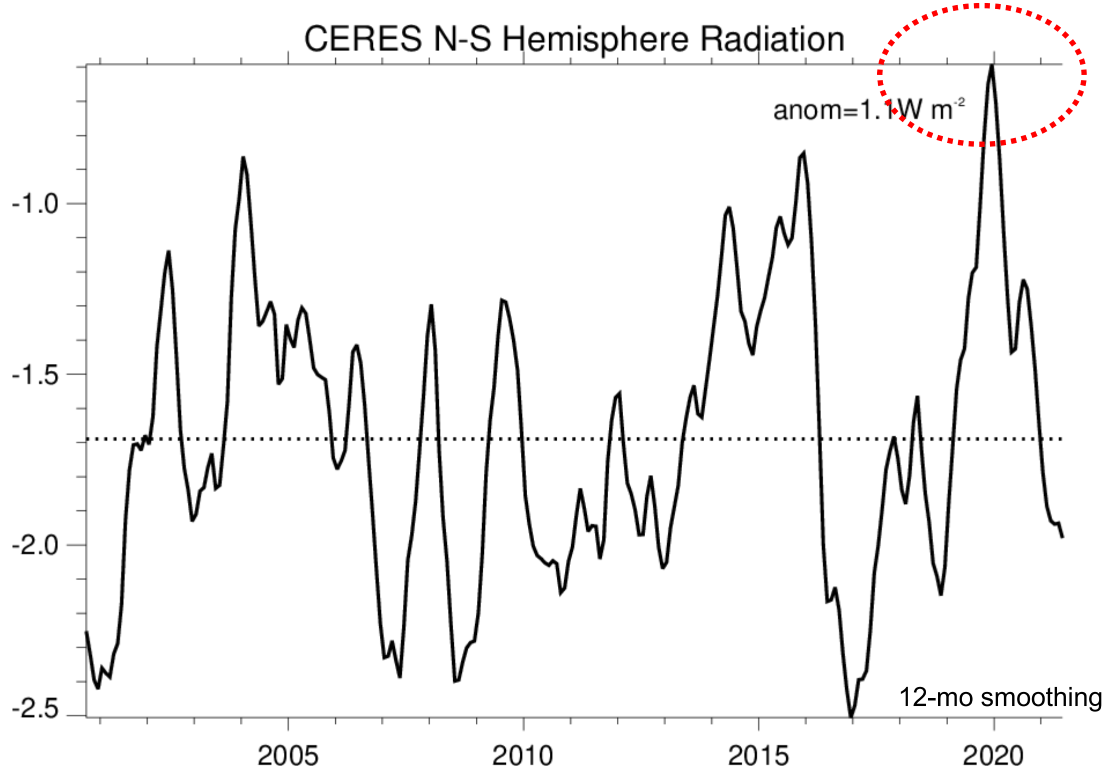


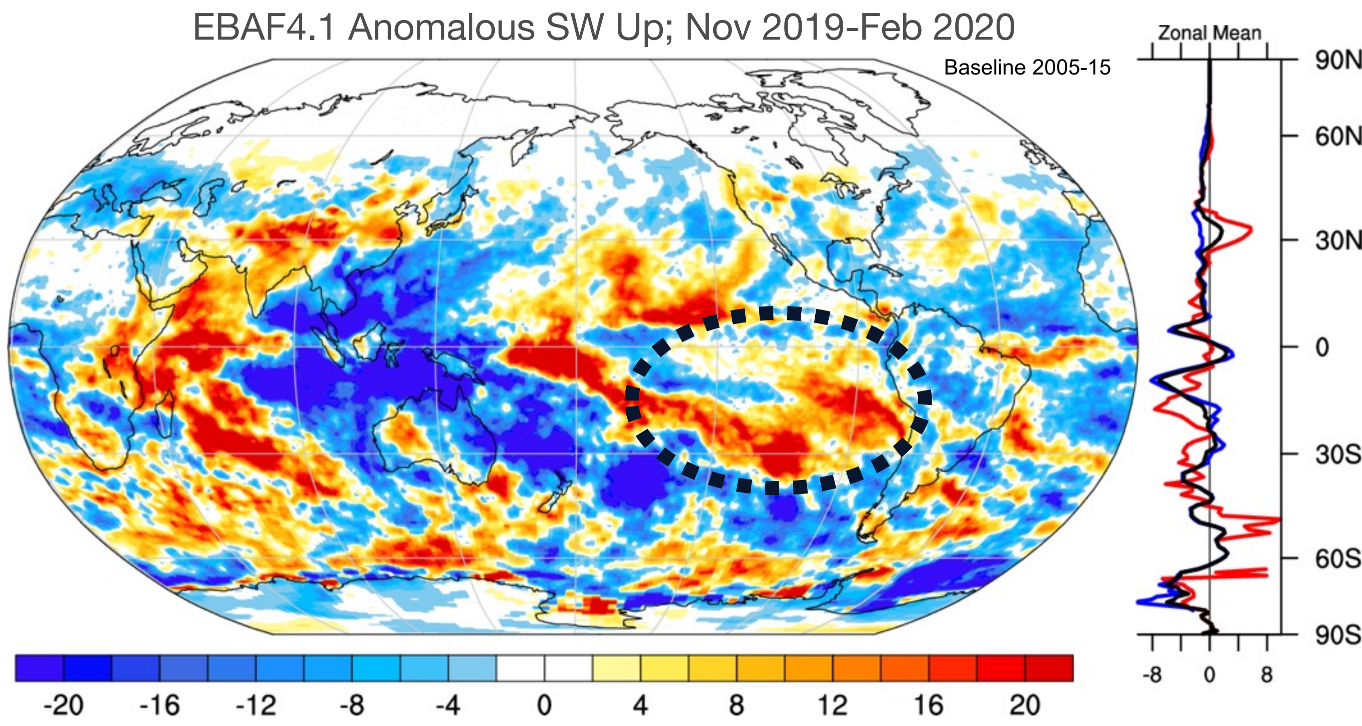
Cloud brightening across the southern hemisphere



CERES: R_T/SW_{up} Anomalies

It is often a challenge to diagnose transient forced climate responses in observations due to noise (i.e. internal variability). Still, some of the same features from the CESM2 forced response are suggested in CERES data.





The net radiative imbalance between hemispheres hit an absolute min in 2020. The minimum coincides with the AOD anomalies identified in Loeb et al. 2021.

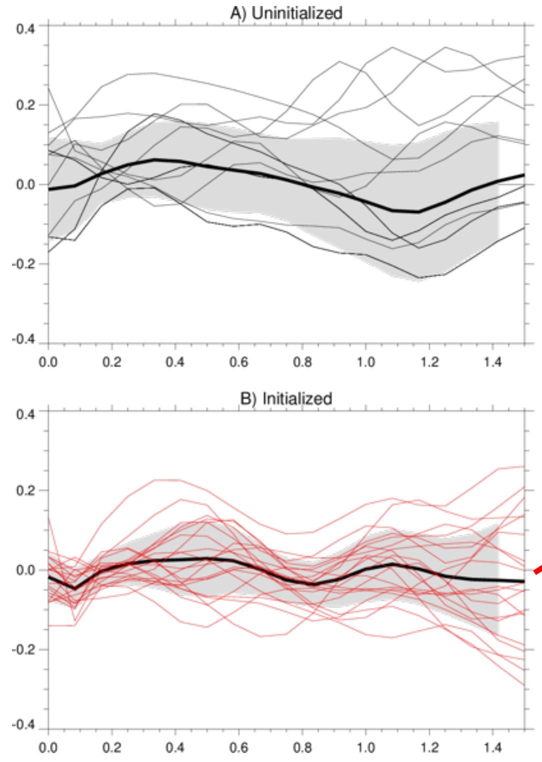
Albedo anomalies in the Southern Hemisphere resembling those simulated (red regions) contributed to the hem contrast min.

CESM2 Wildfire Initialized Prediction Experiments (SMYLE)

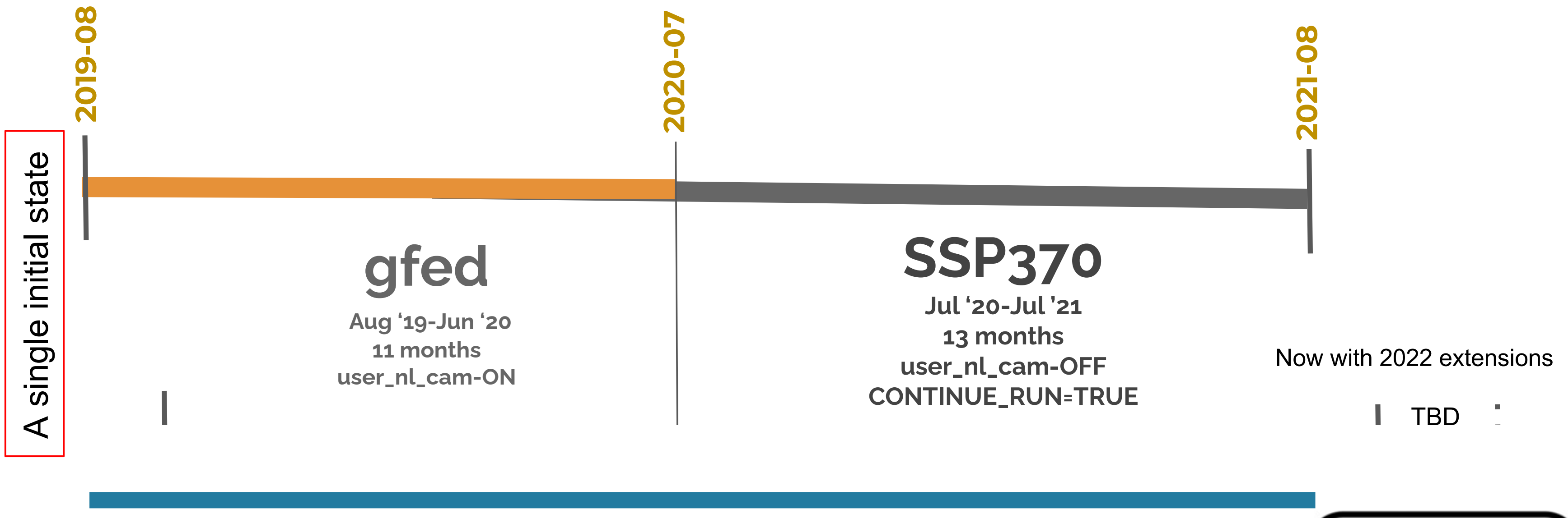
CESM2 SMYLE-AUFIRE Simulations
Date Range: 2019-2021
Number of Members: 30x2 members

Science Question:
Do the 2019-2020 Australian wildfires influence the occurrence of successive ENSO events and if so what are the relevant mechanisms?

YES, via a sequence of radiative and thermal responses.



SMYLE-AUFIRE Simulations



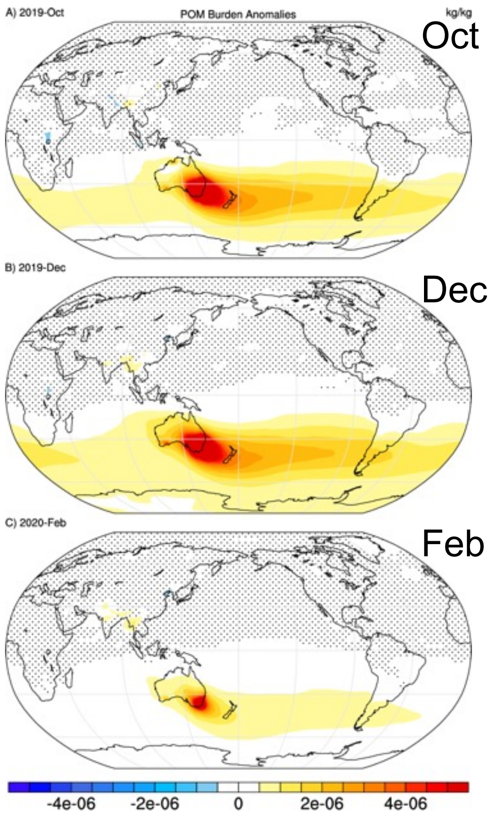
Default SMYLE runs (clim biomass)

CESM2 Wildfire Prediction Experiments (SMYLE)

CESM2 SMYLE-AUFIRE Results

Primary Organic Matter Burden Anomalies

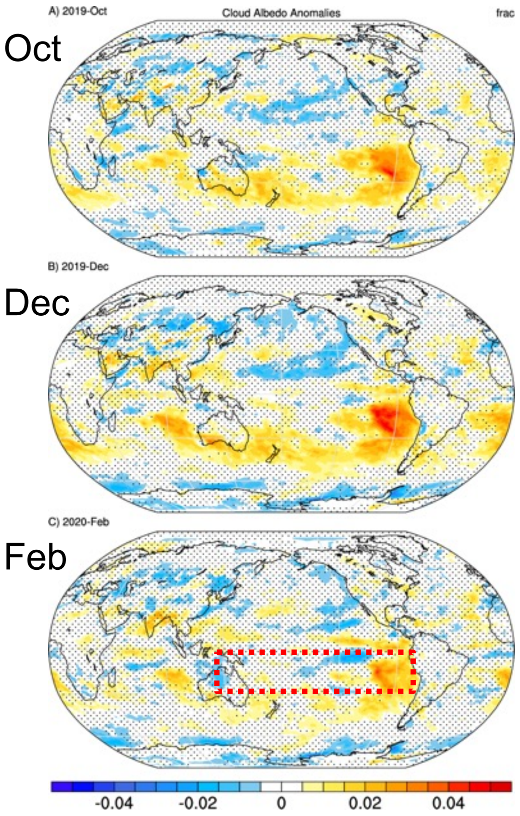
Emissions Max: Dec 2019, and largely gone by March 2020



The Australian wildfires provided a pulse of CCN to the pristine southern ocean atmospheric environment. The pulse is short-lived and dissipates by March 2020. The timing of CCN in the model agrees closely in timing and magnitude of the AOD max reported in Loeb et al. 2021 from MODIS.

Cloudy Sky Albedo Anomalies

Albedo Max: Jan 2020, and largely gone by April 2020

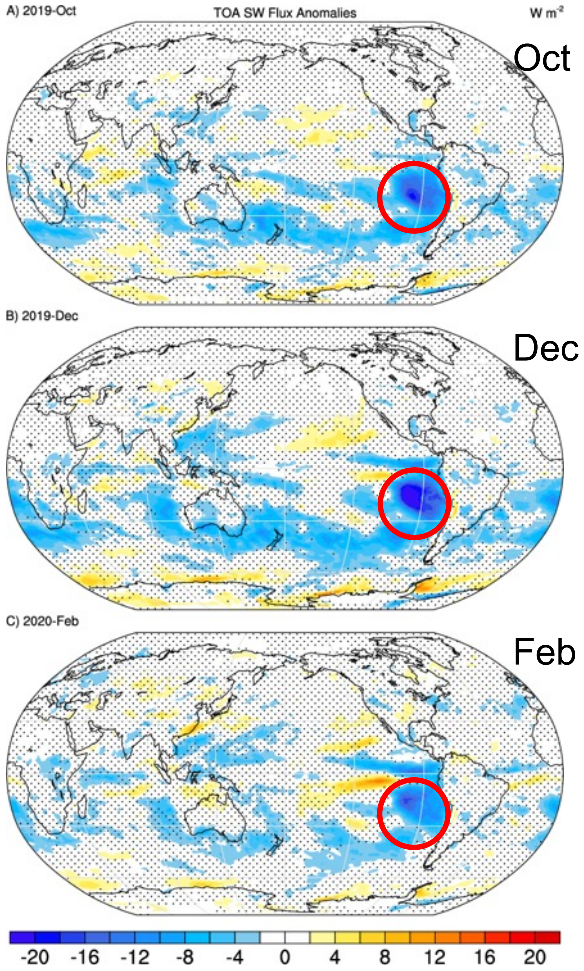


It takes about a month for the aerosols to be transported across the southern oceans. Clouds brighten and last longer in response to the CCN – but not uniformly. Eastern basin, low cloud decks brighten the most. CERES data also show elevated albedo during this time.

CESM2 Wildfire Prediction Experiments (SMYLE)

TOA Solar Radiation Anomalies

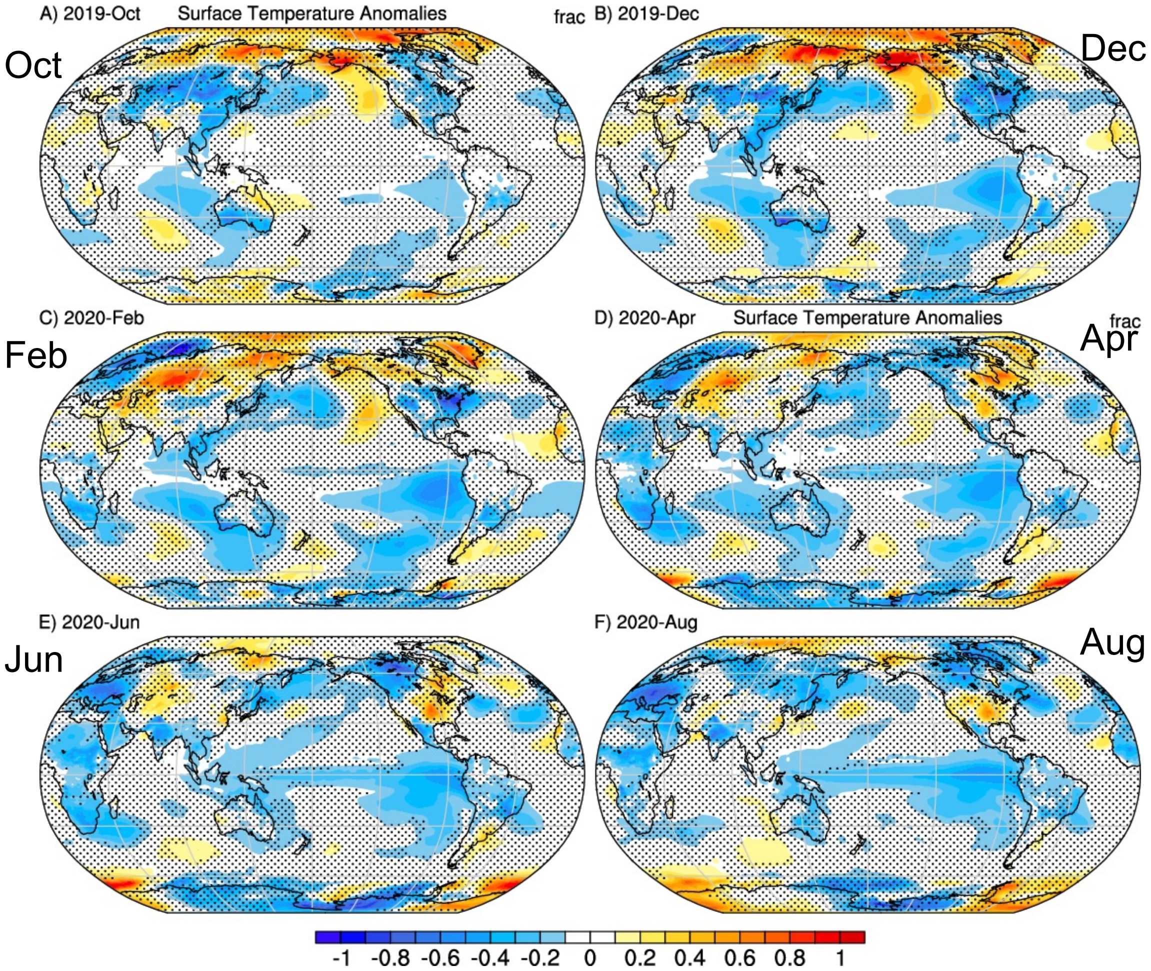
Radiation Max: Jan 2020, and largely gone by April 2020



With the brighter clouds, and coincident with the southern hemisphere maximum in solar insolation, large decreases in TOA net solar radiation are simulated in early 2020.

Surface Temperature Anomalies

Cooling Max: May 2020, persisting through 2020



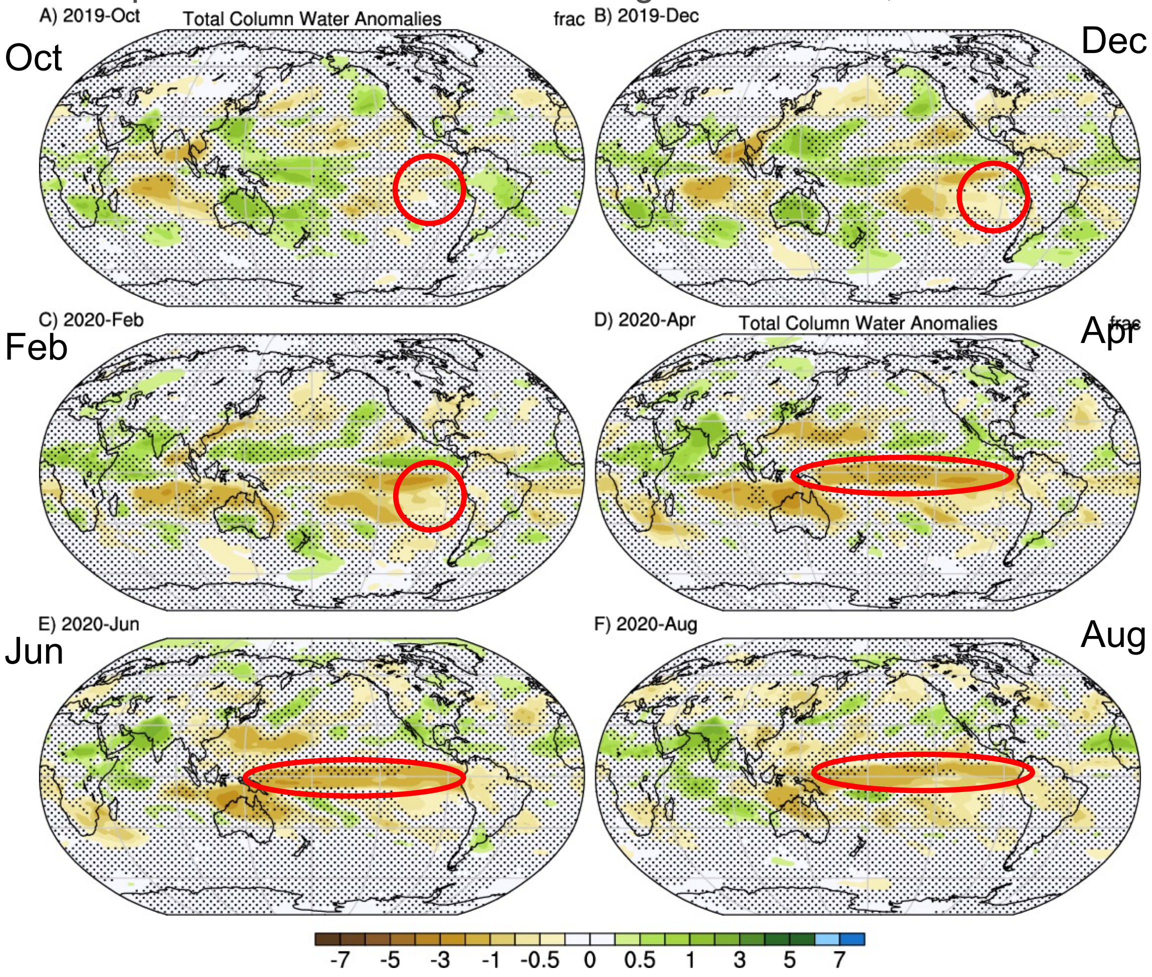
The decreased absorption of solar radiation cools the surface. As these regions lie upstream from the trade winds, temperature anomalies are successively advected into the tropics.

NCAR | UCAR

CESM2 Wildfire Prediction Experiments (SMYLE)

Precipitable Water Anomalies

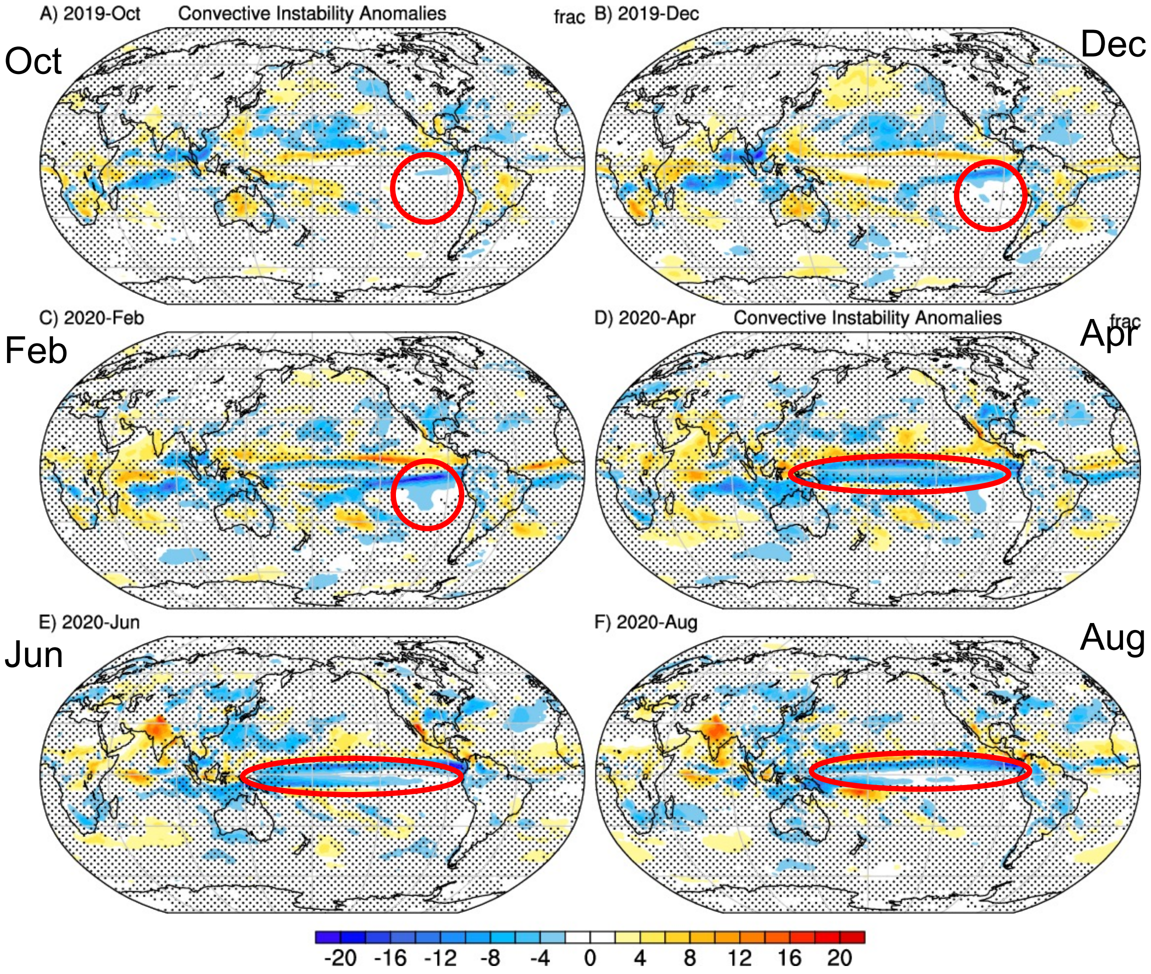
Precipitable Water Anomalies Emerge in Dec 2019, then Advect



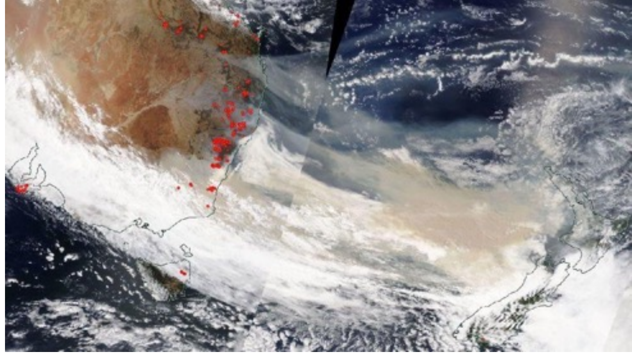
Accompanying the surface cooling is a reduction in total precipitable water, emerging in the southeastern Pacific tropics and then advected by the trade winds into the deep tropics.

CAPE Anomalies

CAPE Anomalies emerge in Dec 2019, then Advect



Reductions in boundary layer moist static energy from advected flow drive CAPE deficits across the tropical Pacific, displace the ITCZ northward, inhibit MJO, and increase the span and intensity of the trade winds on the equator.



Summary: Part 1 Australian Wildfires

- The Australian fires drove increases in biomass burdens and cloud condensation nuclei across the Southern Ocean.

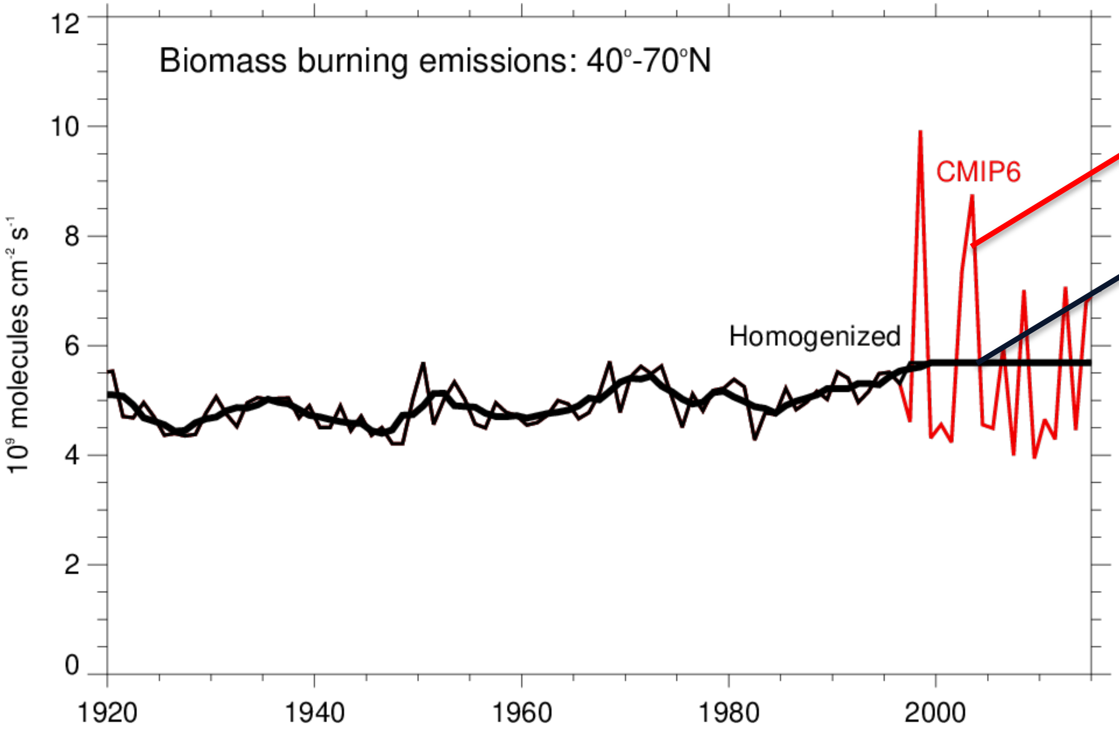
- Via the 1st and 2nd indirect effects aerosols brightened clouds, particularly in the subtropical cloud decks, modified further by cloud feedbacks.

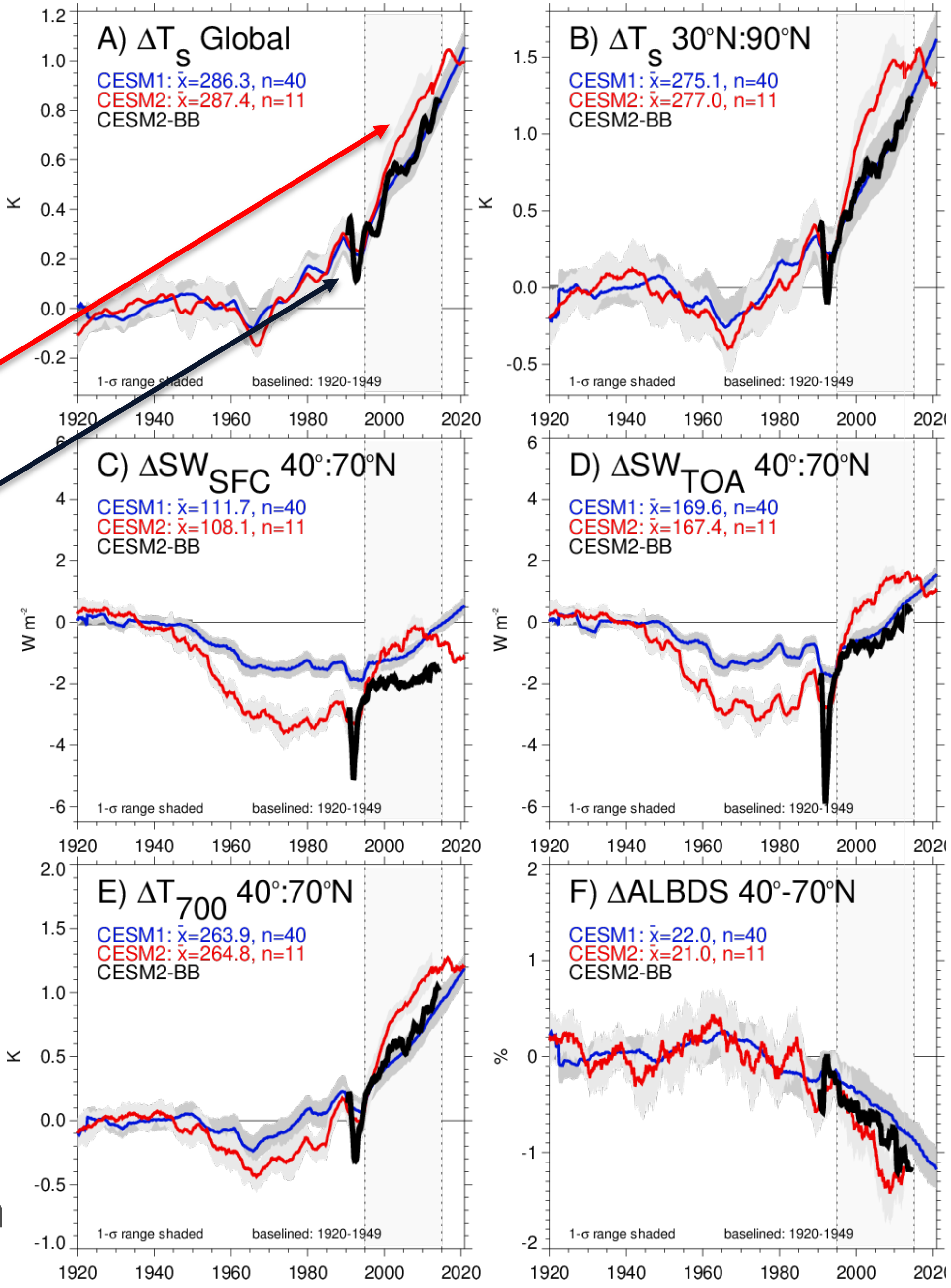
- The reduction in absorbed solar radiation, cooled the surface and dried the lower troposphere, leading to an advection of low moist static energy (MSE) into the deep tropics.

- Reduced MSE decreased CAPE and deep convection was displaced northward. In response, easterly winds intensified along the equator and the MJO likely could not propagate as far east in the WPO. Both effects increased the odds of an ensuing La Niña.

2) Impacts of Wildfire on the Recent Historical Record in CMIP6

(Fasullo et al, 2022: Spurious Late Historical-Era Warming in CESM2 Driven by Prescribed Biomass Burning Emissions, Geo. Res. Lett., doi:10.1029/2021GL097420.)





Above: Annual CMIP6 prescribed biomass (BB) emissions – a large increase in variability 1997-2014 (the satellite era).

Right: The simulated impact of **homogenized BB emissions** (mean conserved, interannual variability removed).

Impacts of Wildfire on the Recent Historical Record in CMIP6

(Fasullo et al, 2022: Spurious Late Historical-Era Warming in CESM2 Driven by Prescribed Biomass Burning Emissions, Geo. Res. Lett., doi:10.1029/2021GL097420.)

The effects of resolved biomass variability are to:

A) Warm the northern hemisphere

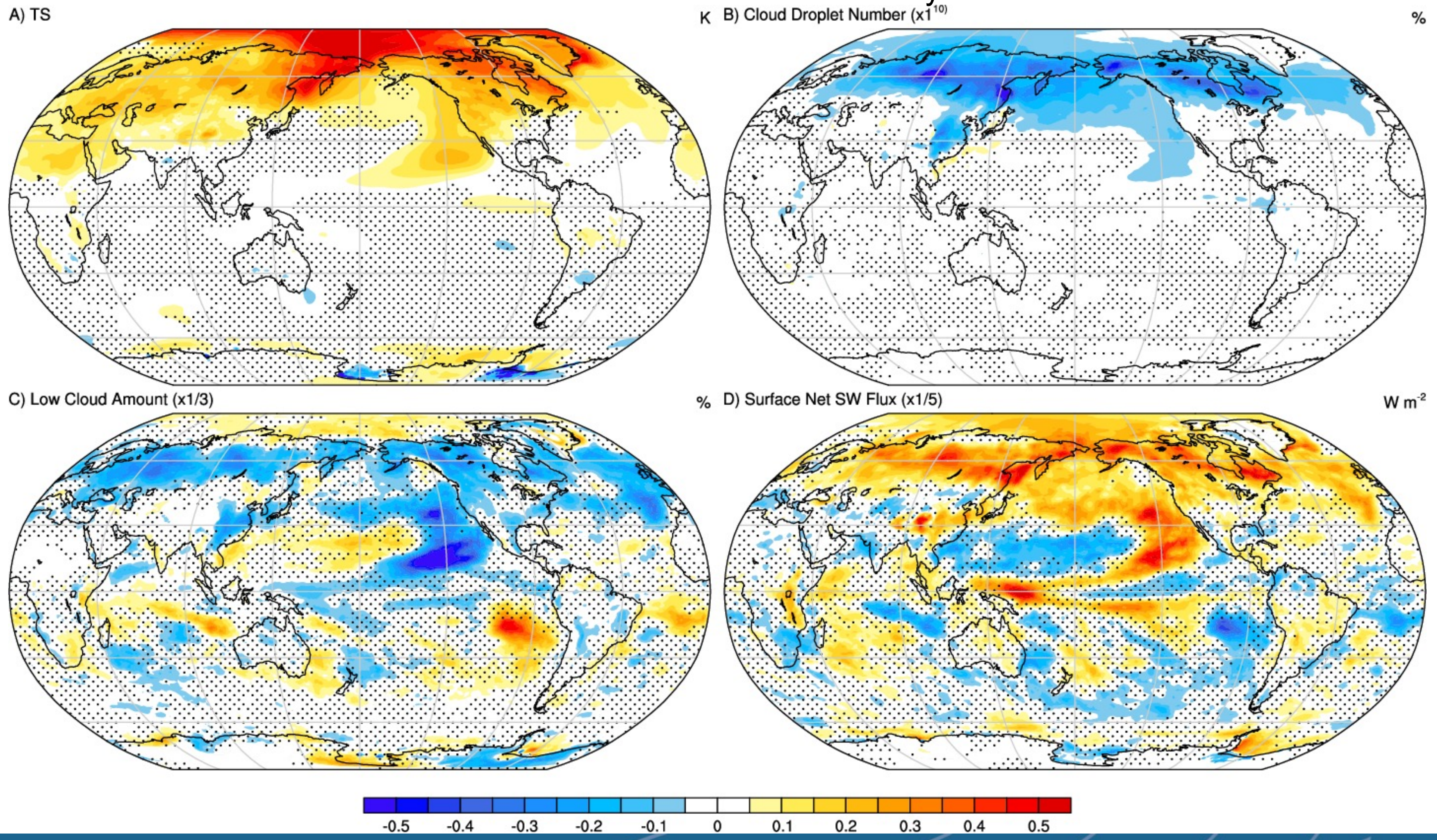
B) Reduce the mean cloud droplet number

C) Reduce low cloud amount, particularly in the northeastern Pacific Ocean.

D) Increase the net surface SW flux

But why?

Mean effects of biomass emission variability: 1997-2014



Impacts of Wildfire on the Recent Historical Record in CMIP6

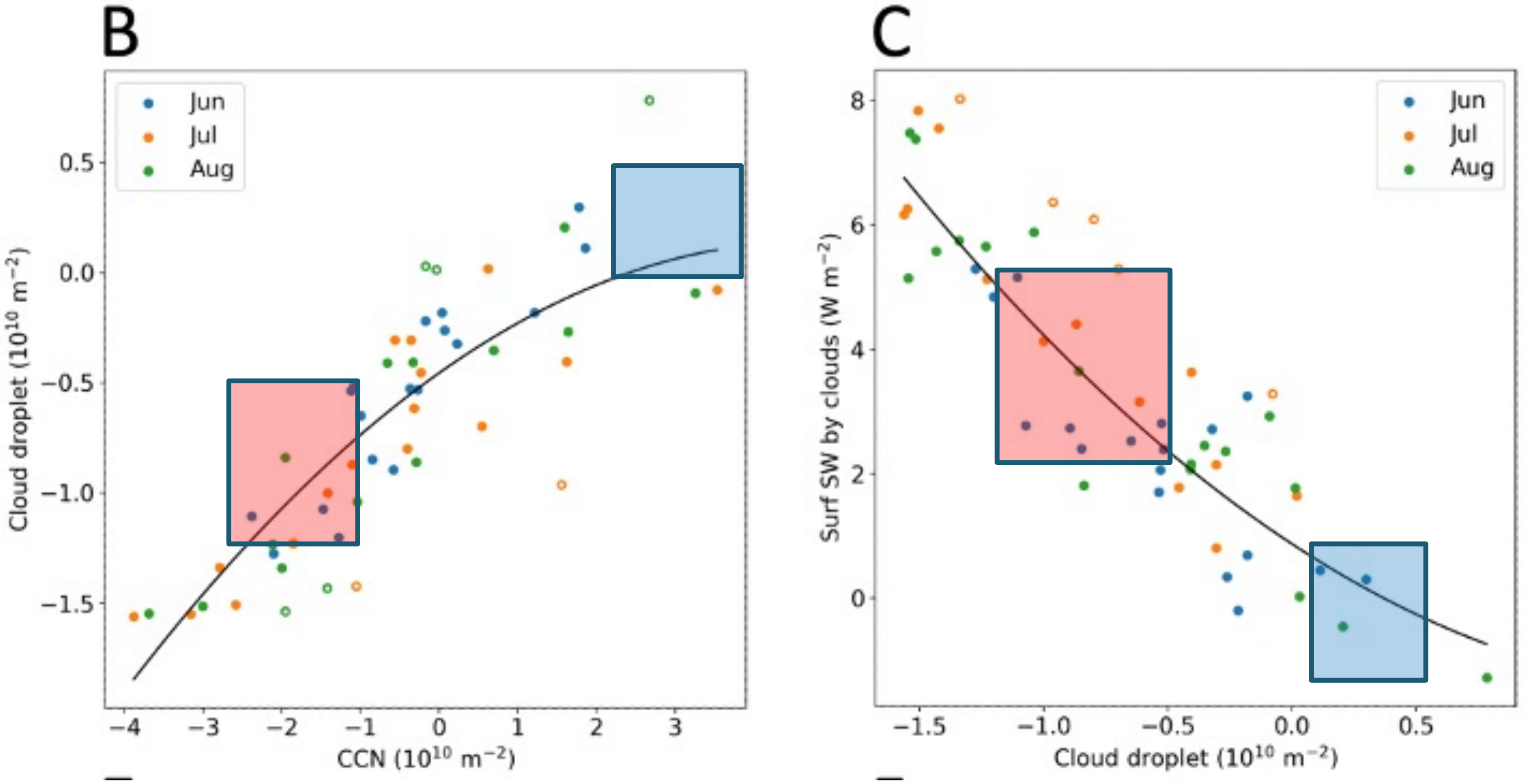
(Fasullo et al, 2022: Spurious Late Historical-Era Warming in CESM2 Driven by Prescribed Biomass Burning Emissions, Geo. Res. Lett., doi:10.1029/2021GL097420.)

Why do variable emissions result in a net warming?

Saturation in the CCN-cloud droplet-SW flux relationships.

Variability in emissions results in **many years of < CCN**, (which have steeper cloud droplet and SW responses)

… and only a **few years of very high emissions** (flatter responses)



Impacts of Wildfire on the Recent Historical Record in CMIP6

(Fasullo et al, 2022: Spurious Late Historical-Era Warming in CESM2 Driven by Prescribed Biomass Burning Emissions, Geo. Res. Lett., doi:10.1029/2021GL097420.)

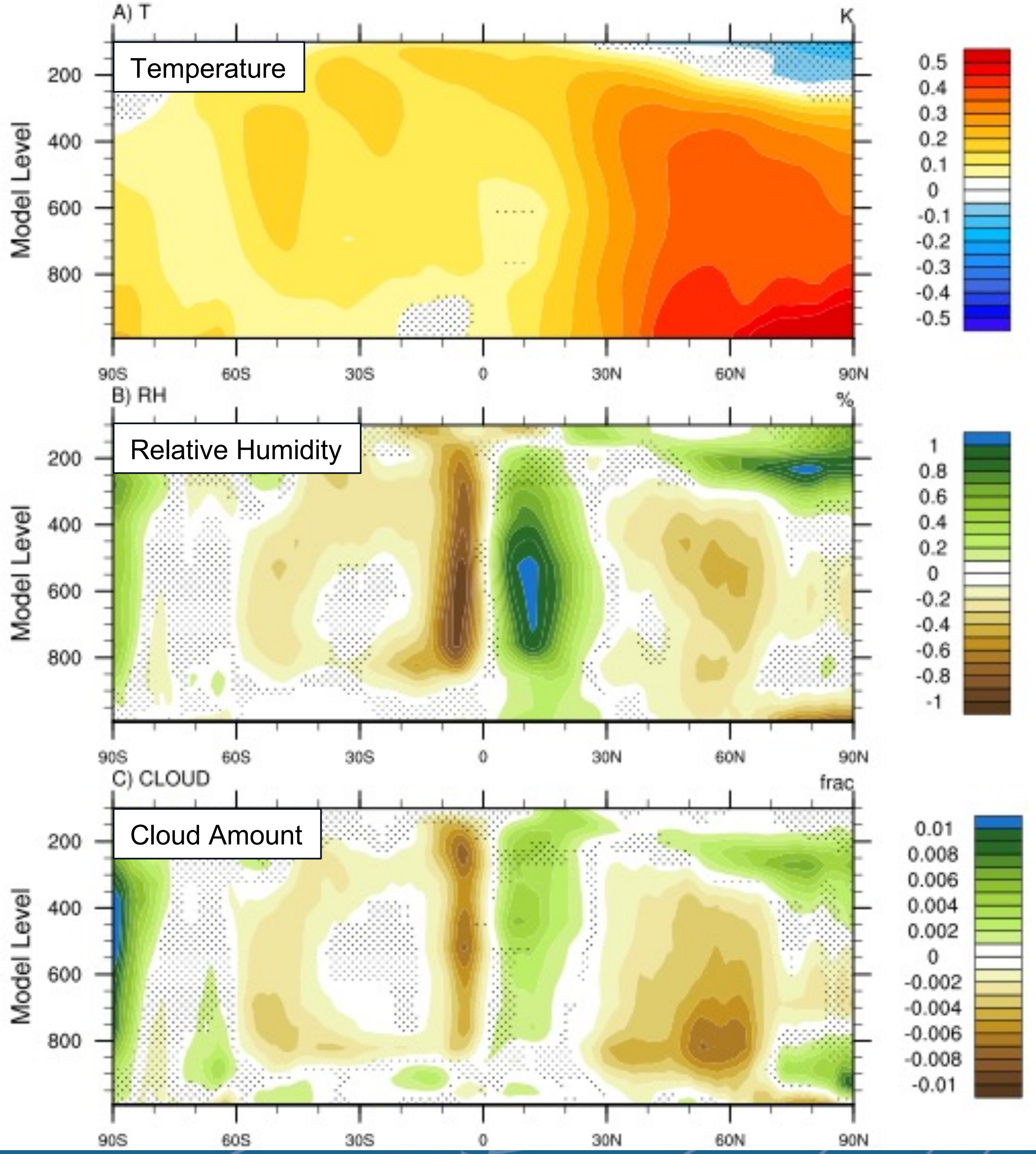
Q: Are responses confined to the NH as TS suggests?

A: No.

A warming of the global troposphere, particularly aloft of 800 hPa occurs.

A northward shift of the ITCZ also occurs.

∴There are important responses globally.



Po-Chedley et al. NCC, submitted: Explaining Tropospheric Warming Rates

The effects of internal variability and spurious biomass forcing largely explain model observation discrepancies in tropospheric warming in CESM2.

Key Point: Late historical era warming discrepancies do not invalidate CESM2 ECS.

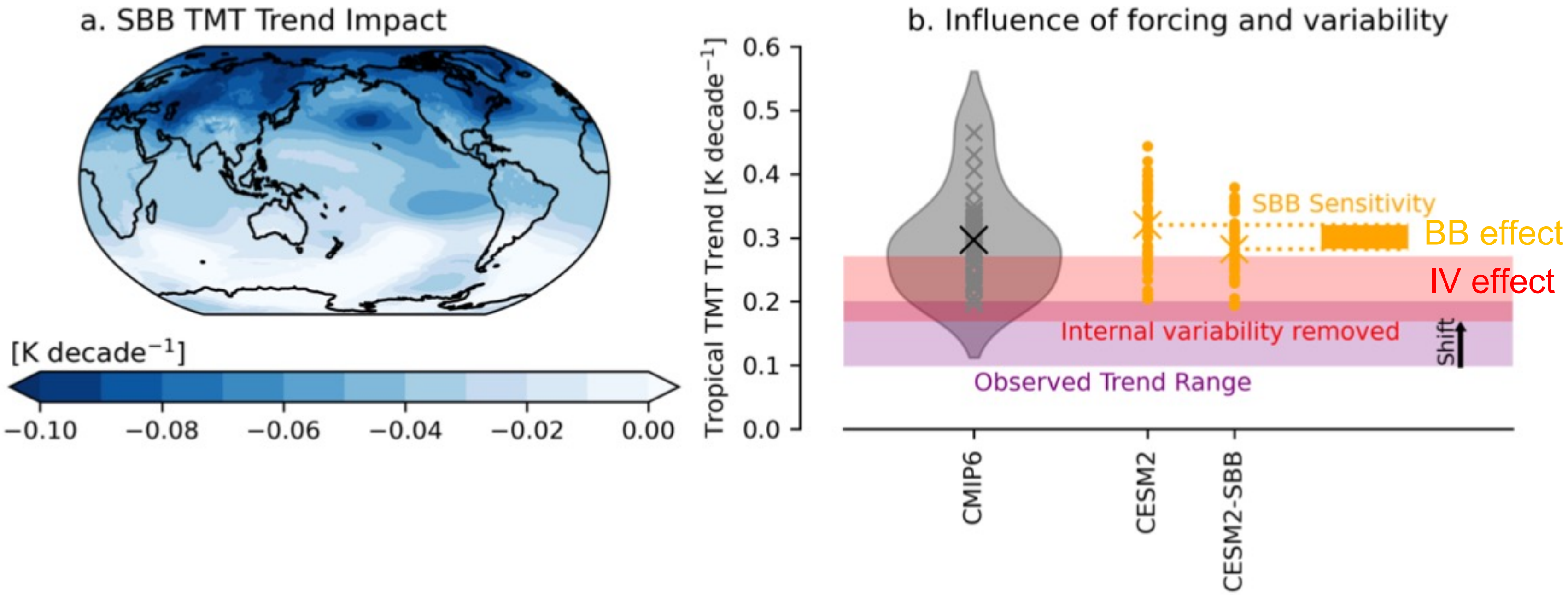
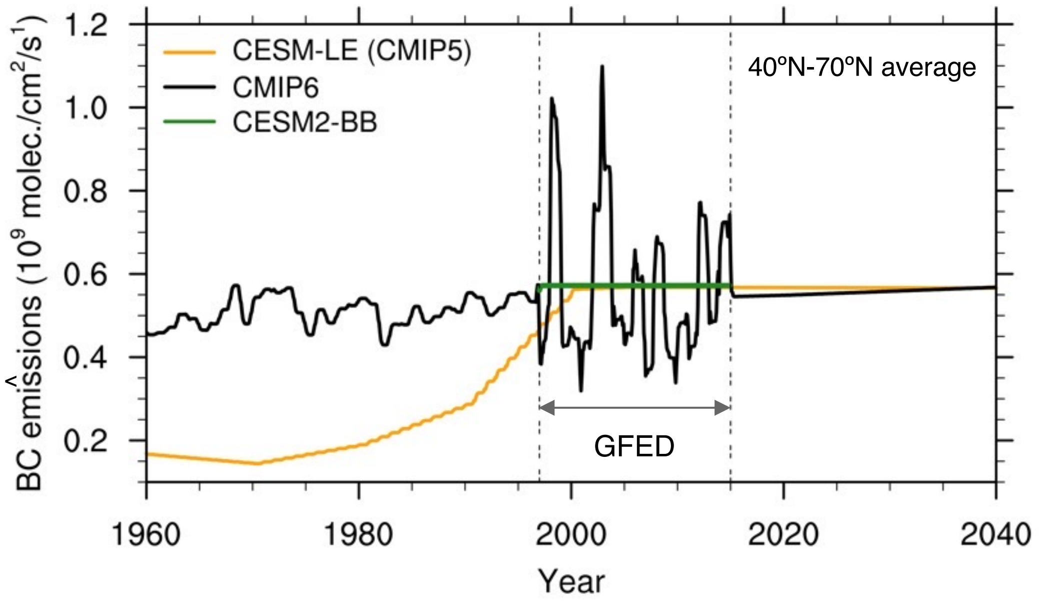


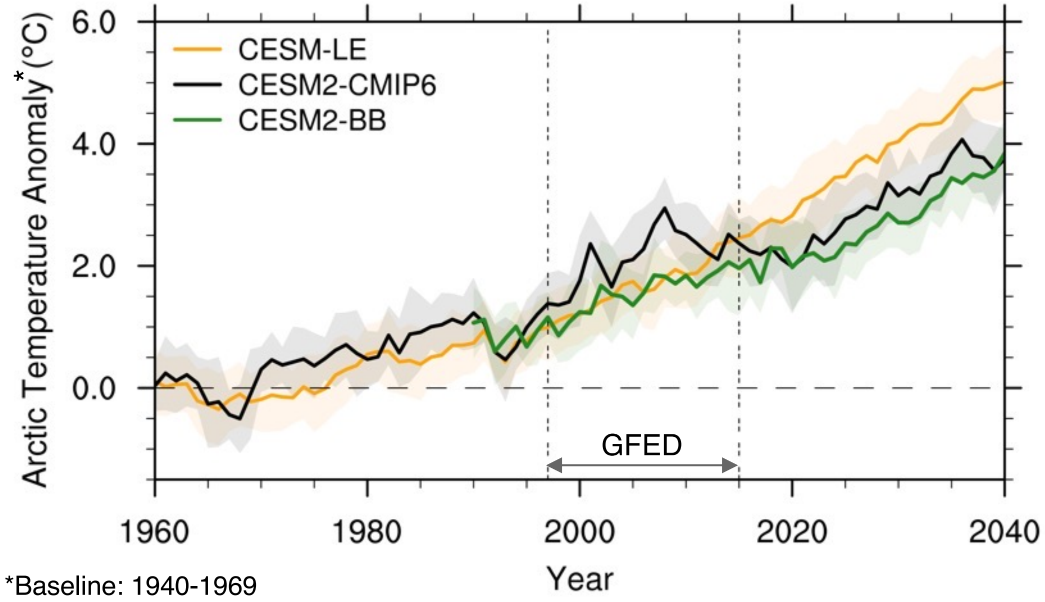
Fig. 4 | Internal variability and forcing artifacts largely explain model-satellite trend difference. **a**, TMT trend (1979 to 2014) for the CESM2-SBB ensemble average minus the CESM2 ensemble average. **b**, Tropical (30ºS – 30ºN) TMT trend for CMIP6 models (gray "violin" probability distribution plot with individual model ensemble averages denoted by X markers and the large black X denotes the multimodel average) and for the CESM2 and CESM2-SBB ensemble members (orange dots with X markers for the ensemble averages). The vertical range of the orange shaded region represents the tropical TMT trend sensitivity to BB aerosol artifacts (CESM2-SBB minus CESM2). As in Fig. 3 we subtract the estimated impact of internal variability (-0.07 ± 0.07 K decade^{-1}) from the observed range of trends (purple shading), which has the effect of shifting the observations upwards (red shading). The magnitude of this shift is denoted with a black arrow.

DeRepentingy et al. submitted Enhanced early 21st century Arctic sea ice loss due to CMIP6 biomass burning

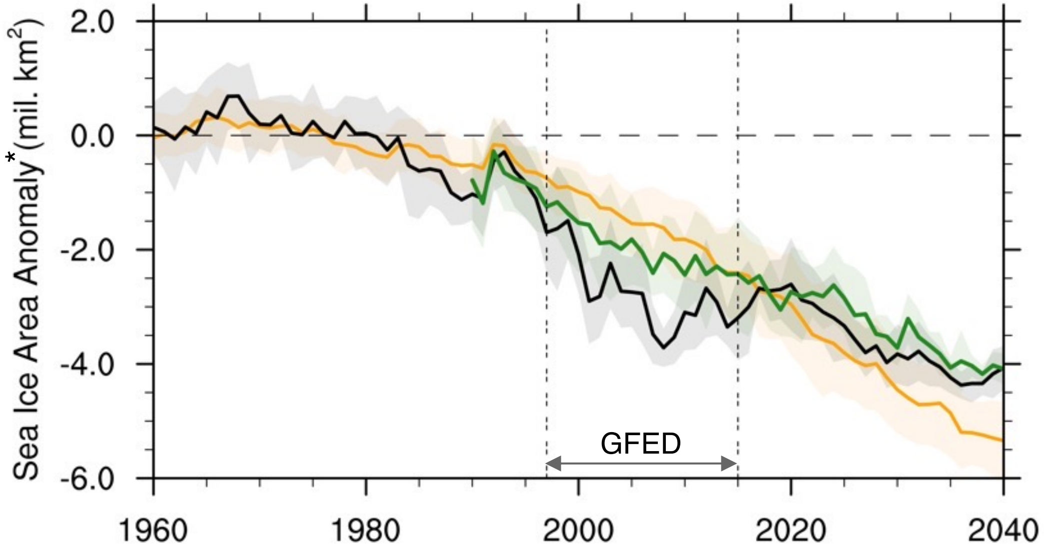
How do biomass effects in CESM2 impact simulated sea ice trends?

Removing the variability in biomass burning emissions leads to reduced Arctic warming and sea ice loss over the GFED period





*Baseline: 1940-1969



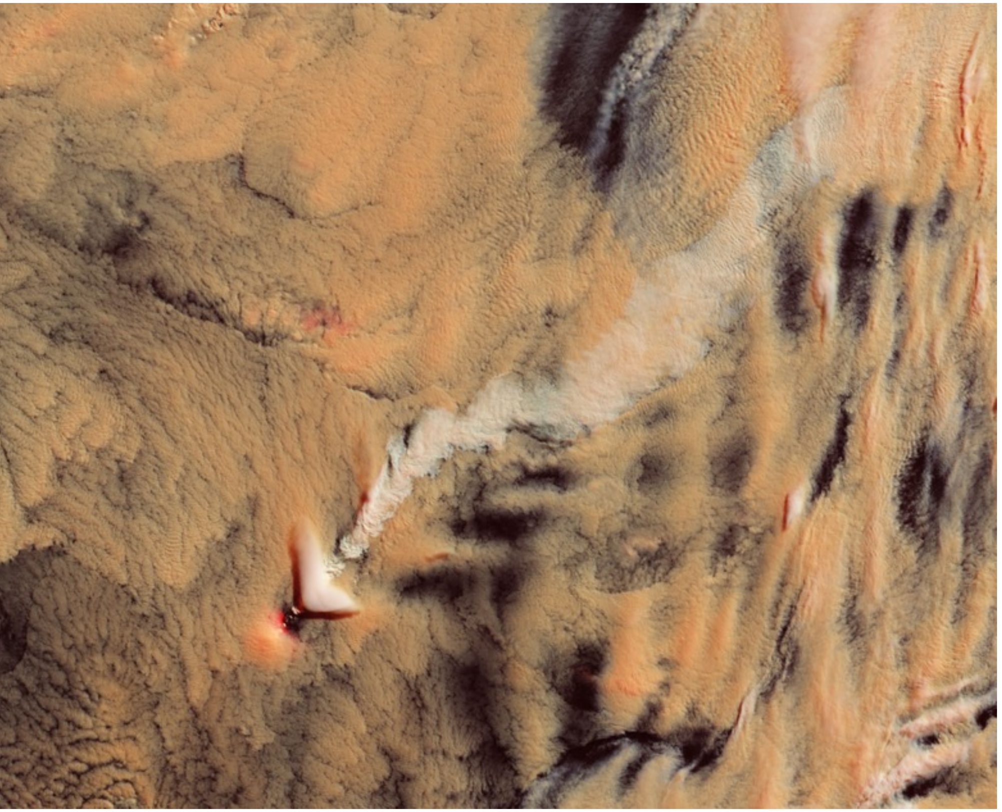
*Baseline: 1940-1969

Low frequency variability in observed sea ice loss is also consistent with the response to observed biomass emissions in CESM2 (reduced rates in recent years).

Ongoing Work

Ongoing Work: CESM2 Evaluation

Is CESM2 adequately simulating cloud aerosol interactions?
Model evaluation with test cases continues, using flux-by-cloud type and PRP data.



Volcanic cloud brightening in the South Sandwich Islands (Mt Michael, OLI bands 7-6-2)

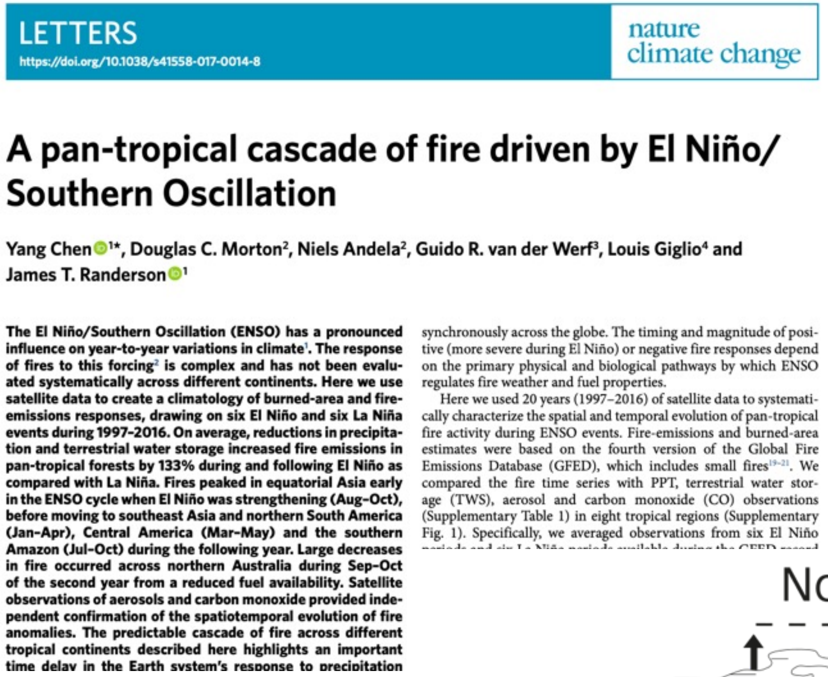
Eruption of Mt Calbuco – Apr 2015

Emerging Opportunity 1
Wildfire as a Coupled Component of ENSO

- In the satellite era, we've learned that wildfire variability in Indonesia, the Americas, and Australia is strongly tied to ENSO.

- ***Given the influence of wildfire emissions on clouds, rainfall, and atmospheric heating, what role does fire play in the ENSO cycle?***

- ***In addition to providing a source of predictability, should wildfire be viewed as an intrinsic component of the ENSO cycle?***



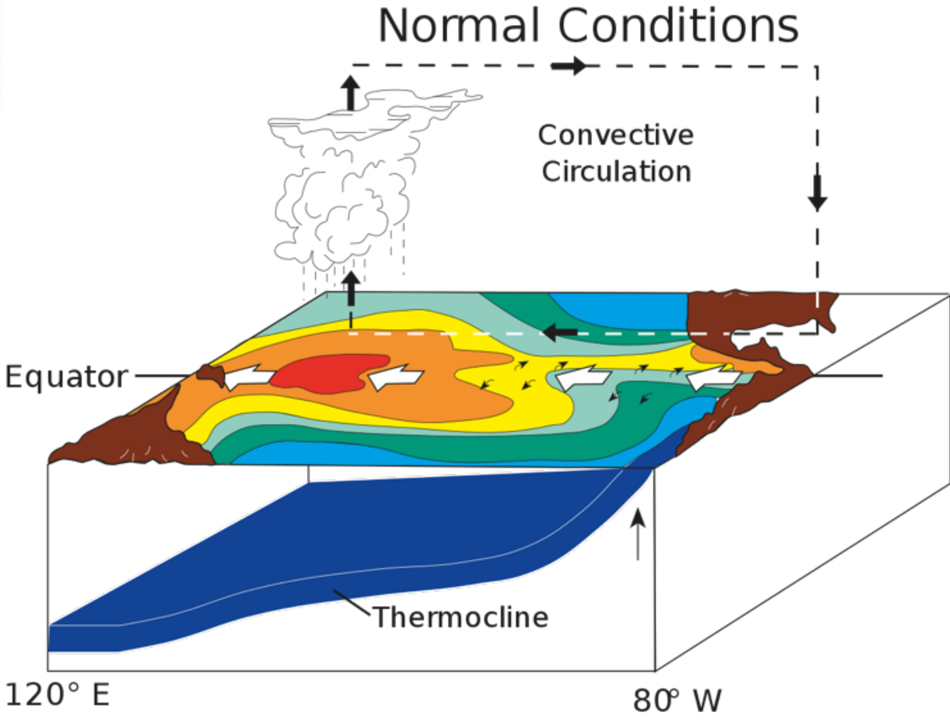
LETTERS
https://doi.org/10.1038/s41558-017-0014-8
nature climate change

A pan-tropical cascade of fire driven by El Niño/Southern Oscillation

Yang Chen[1*], Douglas C. Morton[2], Niels Andela[2], Guido R. van der Werf[3], Louis Giglio[4] and James T. Randerson[1]

The El Niño/Southern Oscillation (ENSO) has a pronounced influence on year-to-year variations in climate[1]. The response of fires to this forcing[2] is complex and has not been evaluated systematically across different continents. Here we use satellite data to create a climatology of burned-area and fire-emissions responses, drawing on six El Niño and six La Niña events during 1997–2016. On average, reductions in precipitation and terrestrial water storage increased fire emissions in pan-tropical forests by 133% during and following El Niño as compared with La Niña. Fires peaked in equatorial Asia early in the ENSO cycle when El Niño was strengthening (Aug–Oct), before moving to southeast Asia and northern South America (Jan–Apr), Central America (Mar–May) and the southern Amazon (Jul–Oct) during the following year. Large decreases in fire occurred across northern Australia during Sep–Oct of the second year from a reduced fuel availability. Satellite observations of aerosols and carbon monoxide provided independent confirmation of the spatiotemporal evolution of fire anomalies. The predictable cascade of fire across different tropical continents described here highlights an important time delay in the Earth system's response to precipitation synchronously across the globe. The timing and magnitude of positive (more severe during El Niño) or negative fire responses depend on the primary physical and biological pathways by which ENSO regulates fire weather and fuel properties.

Here we used 20 years (1997–2016) of satellite data to systematically characterize the spatial and temporal evolution of pan-tropical fire activity during ENSO events. Fire-emissions and burned-area estimates were based on the fourth version of the Global Fire Emissions Database (GFED), which includes small fires[19–21]. We compared the fire time series with PPT, terrestrial water storage (TWS), aerosol and carbon monoxide (CO) observations (Supplementary Table 1) in eight tropical regions (Supplementary Fig. 1). Specifically, we averaged observations from six El Niño

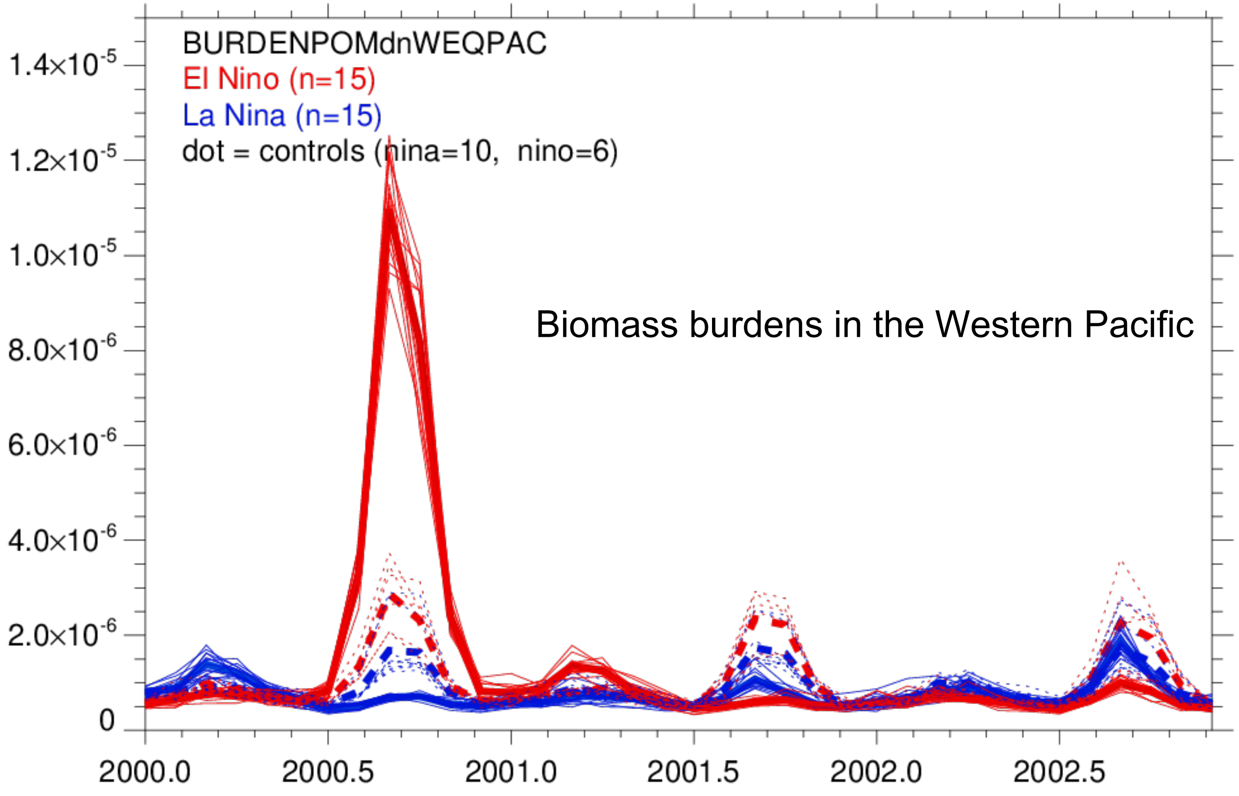


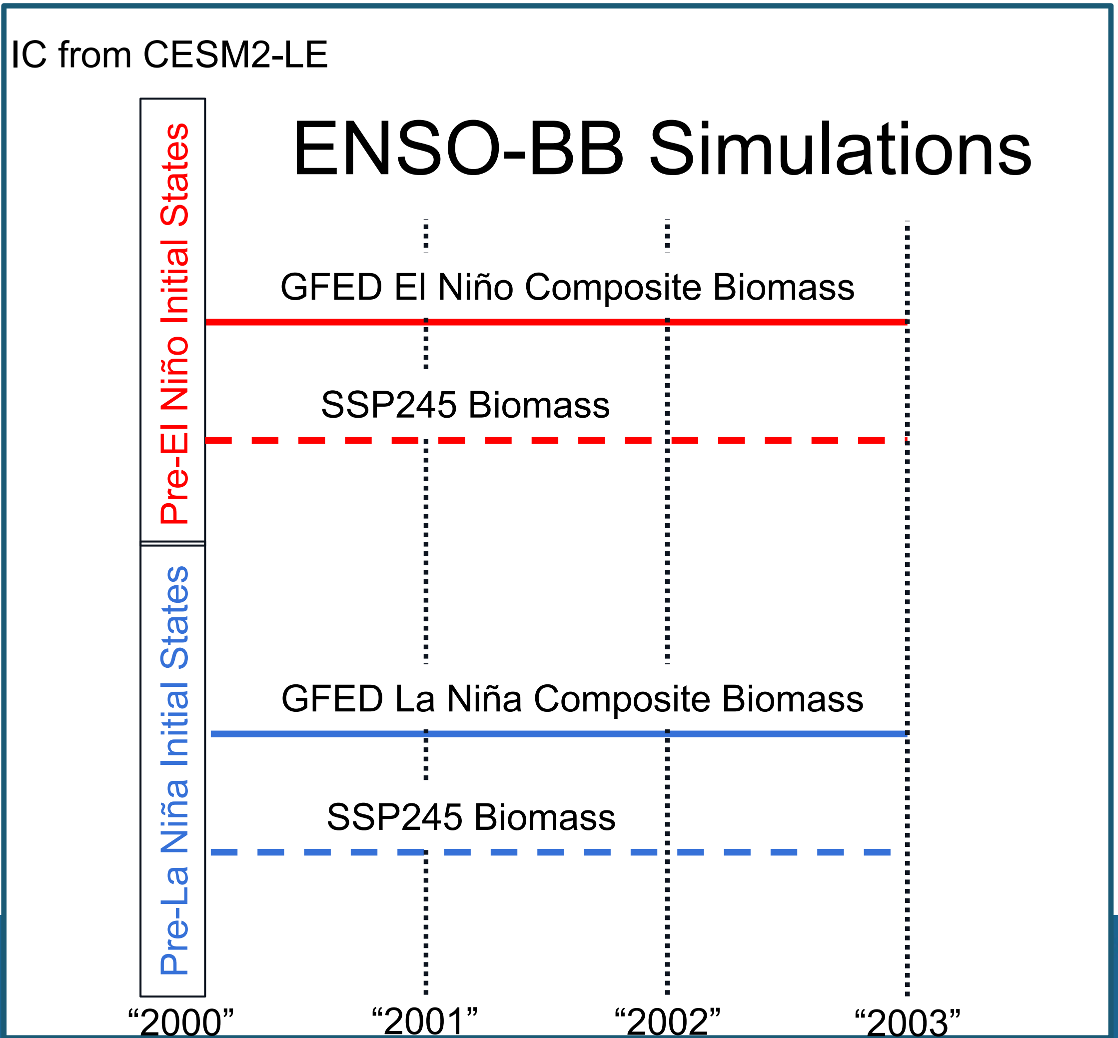
Targeted Experiments: CESM2 ENSO – Biomass Simulations

CESM2 Idealized ENSO Biomass Simulations
Date Range: Idealized
Number of Members: 25x4 members

Science Question:
Do biomass emissions during ENSO influence its evolution?
e.g. due to cloud aerosol interactions?

Approach: Prescribe ENSO-phase emissions as observed by GFED.



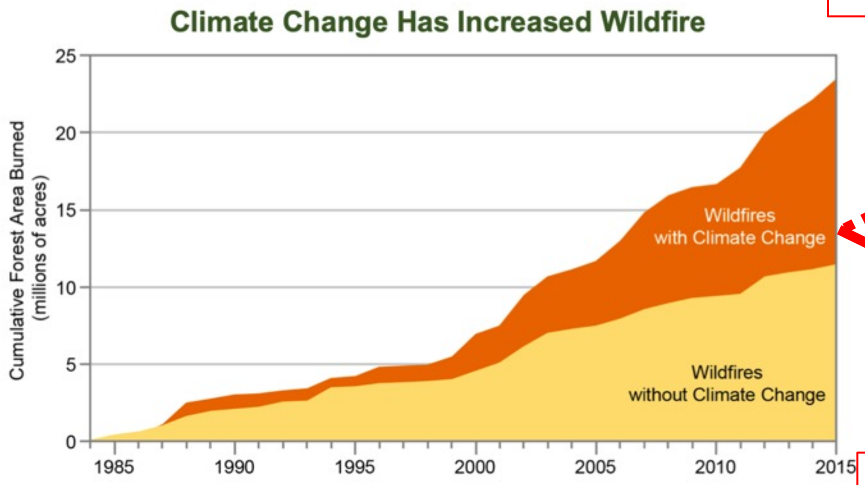


Emerging Opportunity 2
Wildfire as an Internal Climate Process

Major uncertainties exist regarding future changes in wildfire arising from climate change. (AR6 projects various regional increases with high confidence but future scenarios prescribe decreases!)

In CESM2 we show fires to be capable of strong climate effects and substantial modulation of cloud properties.

What are the consequences for cloud feedbacks and climate projections?



The cumulative forest area burned by wildfires has greatly increased between 1984 and 2015, with analyses estim area burned by wildfire across the western United States over that period was twice what would have burned had cli not occurred. *From Figure 25.4 (Source: adapted from Abatzoglou and Williams 2016).*

What is the climate response to a more realistic depiction of fire?

Prescribed 21st C trends depicted in most future climate scenarios.

AI Generated Artwork
Biomass Burning Wildfire Climate Change

Conclusions

- Wildfire effects **on** climate are real and likely to strengthen into the future – but they remain poorly understood.
- In CESM2, wildfire and wildfire variability can influence large-scale warming patterns and the evolution of ENSO.
- Simulating wildfire as an internal component of the climate system, and its interactions with ENSO and as a feedback in a warming climate, remains in its early stages but will be a central focus over the coming years.

Using CERES data to guide CESM development will be essential in building confidence in our ongoing exploration of wildfire's climate role.

END